DISCOVERY

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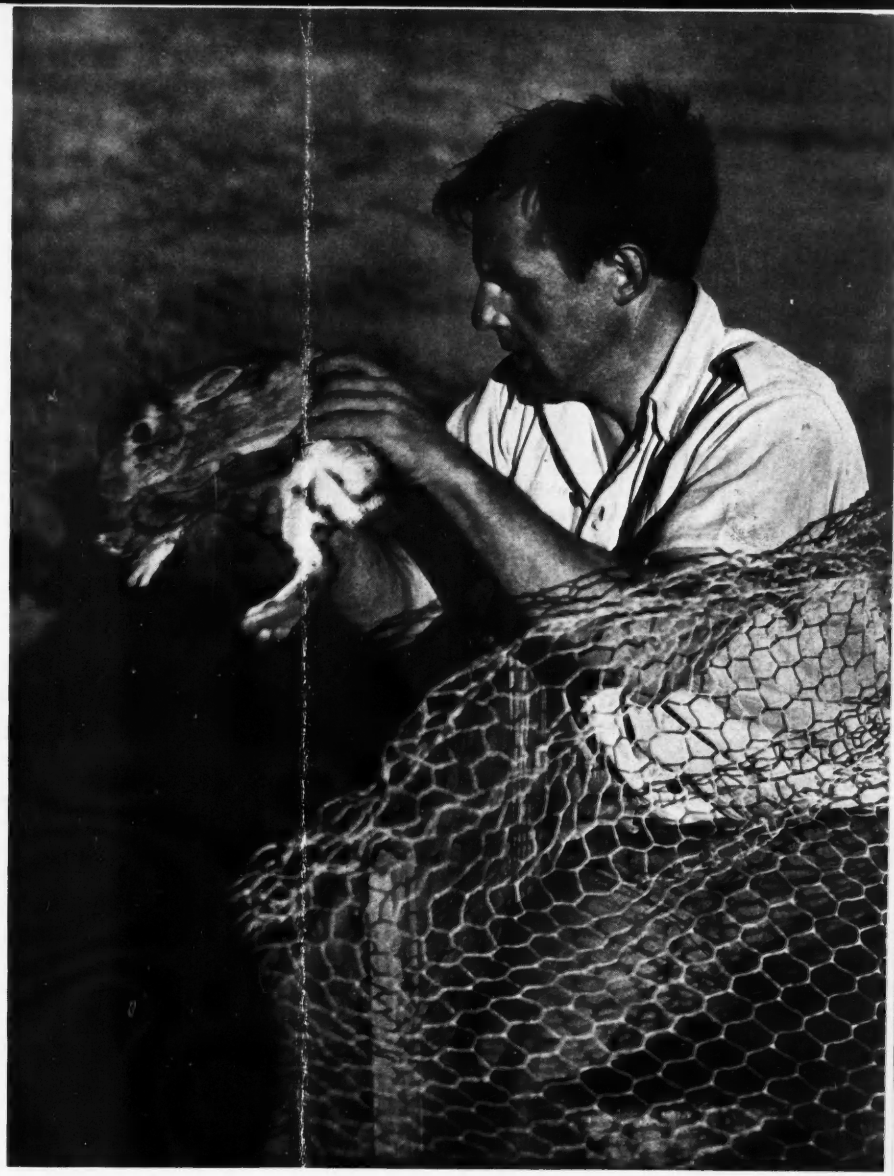

Releasing a rabbit infected with myxomatosis (see pictorial feature, "Australia's War Against the Rabbit")

JUNE
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THE MAGAZINE OF SCIENTIFIC PROGRESS

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The Progress of Science

Should the Universities Concentrate on Producing Specialists?

THOSE who sow the wind must always be prepared to accept the risk of reaping a whirlwind. This is a risk which a university takes when it invites a public figure from outside the academic world to give an address. Such a person cannot be expected to indulge in vague generalities; usually he will wish to give the students the benefit of his own personal experience, and it should surely be no occasion for regret if his straight-from-the-shoulder talk contains a few hard and unexpectedly painful punches, for then one can feel sure that the full force of his experience is behind his speech. More than one university has had recent cause to appreciate these points. There was, for instance, the recent occasion when Sir Godfrey Ince, Permanent Secretary to the Ministry of Labour, somewhat shocked his university hosts who presented him with an honorary degree by turning his speech of thanks into a commination service. He roundly condemned them for turning out so many arts graduates while the country relied for its existence on having enough technical men with the right kind of mind.

Now Sir Arthur Smout has let the technical men have the other barrel in a contribution at a conference called jointly by Birmingham University, the Federation of British Industries and the Birmingham Chamber of Commerce (of which organisation Sir Arthur is president). His speech was an extempore one that must have made a powerful impact on his audience, not merely because of Sir Arthur's position (he is both a group director of Imperial Chemicals and a member of the main board of I.C.I.), but also because of his long experience of the needs of technological industries.

Stressing that he meant everything he said, he criticised the university courses for their "concentration and narrowness", pointing out that the country's greatest need was for inspired leadership. This would not come from men who had spent their most formative years in specialisms such as nuclear physics and electronics. The curricula appeared to industrialists to be so overloaded that the undergraduates had no time to think. He did not decry the men who studied nuclear physics and electronics, for he had the greatest respect for them as men and scientists, but they could be fitted into industry only in small numbers in very limited spheres.

All he asked of universities was that they should develop character and train men and women in the fundamentals and the humanities. Given the right material, industry could then teach it the "business" in two years. Many new entrants into industry from the universities seemed to expect preferential treatment and "spoon-feeding": industry owed no undergraduate a living.

The university representatives naturally reacted to this homily on a Disney fable, and pointed out that it takes time to become acclimatised to any new environment. They did not produce, however, an answer to the charge that over-specialisation can produce individuals who are immune to change and for whom the environment must be created.

There are too many indications that opinion is hardening on both the academic and industrial sides as to the type of training required for a university graduate. The industrialist is, oddly enough, insisting more and more that students should be trained mainly in fundamentals. The universities insist that more and more time is needed to cover all the subjects required for a degree. They have been allowed, without protest, to lengthen the degree courses from two years after the intermediate examination to three. Some authorities even talk in terms of four years. All this has taken place since the war, when industry is desperately short of graduates, and at a time when compulsory military service also takes its large share of a man's best working years.

The views of industry and the outside public are not sufficiently understood in the academic world and, where they are understood, are all too often ignored. In many universities, there exists a mechanism for the representation of the lay view. In London University, there has just been an appeal to the Privy Council over a proposal to increase the membership of the Senate in a way which would diminish the relative representation of old graduates, that

is, the lay element. The energy devoted to what seemed a rather minor battle might well have been used for a movement to reform and simplify university teaching and the examinations which test it. One example from the present state of London University examinations should suffice to show that there is such lack of direction that the machine is out of control. For a London degree in Economics it is now possible for a student to choose his subjects from ninety options!

The particular conference at which Sir Arthur Smout spoke out had been called to discuss the facilities for advanced studies in engineering at Birmingham University. Prof. F. H. Garner has said in *The Times* that these courses were begun at industry's request but are receiving inadequate support. The reluctance of industry to take men out of the works to send them away for a year's study can be understood in view of the difficulties in getting men. The average professional life of a scientist is thirty years. If nearly three years are to be lopped off by the demands of longer degree courses and military studies, nearly ten per cent more men are required to maintain existing levels, without raising them.

If this country's state is considered serious, and recovery dependent to a large extent on technical adequacy and initiative, the place of the scientist and his training needs to be thought out afresh. If military service prevents proper organisation of the university education of scientists, it ought to go. Equally the university teachers ought to realise that there is a school of thought opposed to the continual lengthening of courses. If unlimited deferment from military service strikes at the basis of universality, so does the exemption of farm- and mine-workers. And it would be arguable that the case for the release of scientists rests on more than expediency.

Technical Progress in the Radio Industry

In the course of little more than a quarter of a century there have been immense changes in radio components. The young enthusiast of today looks with stupefied amusement on the components of, say, 1923—tuning coils on cylinders several inches in diameter, home-assembled variable condensers, thick wood and ebonite used for cabinets and panels, loud-speakers like enormous ear-trumpets. In the span of a single generation such things have become museum pieces.

National and commercial demands have in this period effected a revolution, for it is commercial demand, or in war-time the national demand, that is the mainspring of technological advance. Evidence of it was provided at the ninth annual exhibition of components organised in London recently by the Radio and Electronic Component Manufacturers' Federation.

One of the demands is, of course, for reliability, both in the sense of different samples being of the same standard and in the sense of enduring performance under varying conditions. The demand for standards has led to the publication of British Standard Specifications for many components, and a manufacturer knows that it is in his own interest to make his products conform to such specifications or some other specification agreed upon by the radio industry. It is in the increased reliability of components that the radio industry has chiefly advanced, for the basic principles of a radio receiver have not changed in thirty years or more, and, in fact, it is possible to find receivers twenty years old still in use in a way satisfactory enough for the owners. So true is this that the British export of radio components has increased in value from less than half a million pounds sterling in 1939 to an estimated nearly ten million pounds this year, a twentyfold increase, whereas the export of domestic radio receivers has increased less then fourfold in the same period.

A good example of a component that has increased in reliability is the fixed resistor. This in radio is normally a small component and is used in very great numbers in any one circuit. Thirty years ago it was not uncommon for such a component, if the resistance of it was intended to be high, of the order of millions of ohms, to be made by the home constructor by drawing a line with a soft pencil across a piece of frosted glass. Needless to say, such a component had a resistance that could vary easily from one to another by 100%. Today the resistors made by Erie Resistor Ltd.—to take a typical company that has been at the job for a long time—have characteristics that make each resistor a work of precision. One of the ranges consist of resistors wound with wire and bonded in a silicone material. Such resistors resist moisture at extremes of temperature, withstand greater overloads, have a high operating temperature (very necessary because resistors consuming power get very hot), are fire-resistant and have wire connexions that are welded to the resistance wire. Another range of resistors, doing the same sort of work as the home-made resistors of a generation ago, consist essentially of a carbon composition. Twenty years ago such a resistor was a black rod with wire connexions at each end in a blob of solder. Today it is in a ceramic case and is elegantly colour-coded to indicate the resistance and the tolerance, which is the percentage variation from the rated value. A tolerance of 1% is obtainable if desired. It is approved by the Services for tropical use. The metallic connexion is a wire on a spring cap fastened over the rod, the whole being contained in a white ceramic case.

Other components have advanced in the same way. Even screws, which have been regularly used for many generations, have been improved, especially with the Philips recessed head, enabling the user to put the screw on the driver and hold it there without an extra hand, thus facilitating the work and eradicating the nuisance of driver-slip and non-centring of the screw. This screw is made by Guest Keen and Nettlefolds, and has been in production for some years. (If such screws were readily available in the retail shops—and they do not seem to be—there is every likelihood that all amateur craftsmen would transfer to them very quickly.) The most recent development in this line of component is the self-locking nut based on a British patent and put into production only very recently. Solders, too, have advanced from the day of lumps of heavy solder and a flux of 'spirits of salts', and now that the patent covering the use of multiple cores has expired several firms are producing solder in the form of wire with cores of flux already incorporated in it.

Probably the most dramatic change in components, however, is their great reduction in size, the so-called 'miniaturisation'. There were, and still are, many war-time

demands for smallness and compactness, such as the proximity fuse in anti-aircraft shells, a complete circuit small enough to be inserted in the head of the shell in order to guide it to the target when it is near enough for the circuit to be set into operation. In peace-time, some of the miniature components so produced have been incorporated into deaf-aid apparatus. There are valves less than an inch long, each complete with its electrodes and connecting terminals. There are variable resistors smaller than a shilling, each with a milled head for the manual adjustment of the resistance. There are capacitors (condensers) about a sixteenth of an inch in diameter made from paper less than a thousandth of an inch thick with a metallic coating only one millimicron thick (a millionth of a millimetre). There is wire so fine that the coating of enamel on it is only a tenth of a thousandth of an inch thick. All these components and many others are not in any way stunts; they have the same high standard of performance as the bigger components.

Something is lost in miniaturisation. High power cannot be handled by a miniature component, and such a component is more expensive than the more normal sort. Nevertheless, the trend is significant, and there seems no reason why in the future many components now in everyday use will not be replaced by their miniature descendants.

The Physical Society Exhibition

THIS well-known annual event in London has been held, with the exception of war years, ever since 1905. Each year thousands of visitors throng the laboratories and corridors and landings of the Imperial College of Science and Technology in South Kensington and look at the hundreds of pieces of apparatus there assembled. At this stage, now that the 1952 event—the 36th exhibition—is over, one may usefully examine the original aims of the promoters, and search for possible ways of adapting those aims to modern needs.

At the first meeting scientists gathered together, some of them with their apparatus wrapped in brown-paper parcels which they proceeded to unpack and show one another the gear they were using. The professional manufacturer of apparatus existed at that time, but he had not developed into an industrialist whose products could be taken directly from the Physical Society Exhibition to the British Industries Fair: modern techniques of display had not then been perfected. Today, there are still many scientific workers who use the exhibition in the way in which it was intended at the beginning; they examine apparatus with a view to extending their own experimental work and their knowledge of what others are doing. This statement applies especially to the work of the university and Government laboratories. There are also many visitors who are in some way connected with the scientific side of industry and who attend the exhibition in order to get an insight into the advance of physics in general. There are also—anyone who has demonstrated at the exhibition knows this to be true—some visitors whose knowledge of physics is negligible and who look on the exhibits in much the same way as that in which they do a morning's sightseeing at the waxworks. (How this can happen when admission is only by tickets issued by the Physical Society is something of a mystery.)

A few of the visitors are young people from fifth and sixth forms, and it is with these, whose intellects are just burgeoning, that the Physical Society could achieve something that would help to solve the problem of the dearth of scientists and science teachers. If the schoolboy scientists were encouraged, especially those to whom South Kensington is not easily accessible, the exhibition could serve as an extremely valuable aid to education in physics.

The apparatus for this education is on show at the exhibition. Nowhere else is such a rich collection to be seen; certainly no science master in public or grammar school could hope in his most optimistic dreams ever to assemble such apparatus for his pupils. Is it realised that there still exist schools where the array of apparatus in

The Moral Obligations of Scientists

A FORETASTE of what Prof. A. V. Hill is likely to say in the course of his presidential address to this year's Belfast meeting of the British Association is provided by his article in a recent issue of the *Bulletin of the Atomic Scientist*. This article, which is entitled "Scientists are Quite Ordinary Folks", formed part of a symposium on the Duty of the Scientist in Society, and the following is a typical quotation from it:

One consideration only in this connexion I would urge, that scientific people do not get an exaggerated idea of their importance, or of their moral superiority, but regard themselves as citizens who have the same moral obligations of honesty, kindness, courage, and tolerance as others. They have no more right to insulate themselves from the common affairs of life, or the common obligations of citizenship, than have other people. If they have political aspirations, or a mission to improve mankind, let them follow these as citizens, not claiming scientific fame or notoriety as justification for public pronouncements on unrelated matters. The integrity and prestige of science are common property and must not be exploited for selfish ends. And scientists should be implored to remember that, however accurate their scientific facts, their moral judgments may conceivably be wrong.

I doubt whether the new importance which natural science has acquired in industrial, national and international affairs, with the inevitable consequence of restriction (in certain fields) of completely free exchange, is a serious deterrent to able young people from entering science as a profession. The field of science is vast, and those who wish can keep out of the special fields where government, or industrial, secrecy prevents free discussion and publication. I should regard as rather hysterical a youngster, with good scientific ability, who was deflected from science simply by fear of secrecy—if indeed one did not conclude, rather, that he really wanted to do something else and was giving a fashionable excuse.

physics is limited to an ammeter or so and some pieces of glassware, with a few antique toys such as the Wimshurst machine? For pupils of such schools a visit to the exhibition would have incalculable effects.

The educational value of the exhibition can be illustrated by examples. Consider the exhibits of the Colour Group of the Physical Society. In the past four years there have been three shows by this group. The first, in 1949, displayed curiosities of colour vision. Toys such as Benham's top, the phenomena of which have not yet been satisfactorily explained, were shown in operation. Has anyone in Great Britain under forty ever seen Bidwell's Ghost demonstrated? The Physical Society exhibit of 1949 showed it. In 1951 the group concentrated on the history of colour science. This was a most remarkable show in which genuine apparatus used by Maxwell and other workers was loaned by the Science Museum, and it was brought up to date by diagrams and models of the Granit micro-electrode technique. There were demonstrations of Goethe's apparatus showing the phenomenon on which he based his theory of colour vision, the historic experiment which Newton carried out in his rooms at Cambridge, and many other phenomena important to the history of colour science. This year the group's exhibit concentrated on the production and modification of colour by physical means. There were demonstrations of colour from dispersion, diffraction, interference, polarisation and selective refraction. Where the colours of a butterfly's wings originate was explained with an example and diagrams based on photomicrographs. The use of Polaroid enabled excellent demonstrations of colour by polarisation to be made.

The models and demonstrations of the Colour Group's exhibits have been arranged by experts from the university and industry. It is safe to say that no pupil has seen more than a tiny fraction of all these experiments in his school physics course. Anyone giving serious attention to the three different exhibits since 1949 has had a course in colour science unequalled anywhere in the world.

Radar techniques, methods of microscopy, developments in automatic computers, 'thinking' machines and many other aspects of physics have all been similarly demonstrated in recent Physical Society exhibitions. The show is, in short, a concentrated course in physics. Arrangements could be made whereby senior pupils of schools anywhere in Great Britain would be admitted in groups by advance arrangement. If this could be done, and Fellows and others requested not to distribute their tickets to non-scientific visitors, an important national service would be rendered, and many potential physicists would not be diverted to other spheres because of the lack of excitement in many school courses. The original founders of the annual Physical Society Exhibition would, we feel sure, have approved such an extension of the purposes they had in mind when the first meeting took place 47 years ago.

The Facts about Foot-and-Mouth Disease

THE present epidemic of foot-and-mouth disease which is causing so much concern to the farming community and the general public is the latest of many which have swept across the European continent over the years. In this instance the epidemic started in Germany last summer, and gradually spread through Denmark, Holland, Belgium and Luxemburg, then into France, and towards the end of the year the first outbreaks were reported in Great Britain. Since then nearly 250 separate outbreaks have been reported in this country; the first of these occurred in the eastern counties and were followed by outbreaks in the south-eastern counties, coincident with the spread westwards through France. Gradually the disease has spread farther and farther northwards, and now affected cattle have been reported as far north as Angus in Scotland. Altogether more than 28,000 animals have been lost by slaughter in this country since the middle of last November; this figure includes 14,326 cattle, 7759 sheep, 6401 pigs and a small number (twenty, to be exact) of goats. At the beginning of May the standstill order on movement of livestock was extended to cover the whole of the country south of the Caledonian canal. This was done after a consignment of calves became infected on their way to Scotland. Some of the animals in contact with these calves were sold in a public market and have since been dispersed over a wide area. The standstill order does not denote any sudden worsening of the foot-and-mouth disease position—it is merely a precaution taken to prevent further spread of disease in a potentially dangerous situation.

It is thought by many that foot-and-mouth disease is a very serious condition, often killing the affected animals, but this is not so. In the majority of outbreaks the animals suffer nothing worse than fever, with spreading blisters in and around the mouth and around the tops of the hooves. As a result of the fever the animals markedly lose condition, and milk production drops or may stop altogether. There follows a long period during which the animal is unproductive and fails to put on weight. Occasionally epidemics occur in which the infecting virus is of a highly malignant type, and in such cases the death rate might be high.

Foot-and-mouth is one of the most contagious of diseases. Local spread is by contact, direct or indirect; motor-cars, lorries, feeding-stuffs, straw and hay, and even the boots and clothing of the farmer himself may be the means of transferring the virus from one farm to another and thus giving rise to new outbreaks.

There are two methods of control available; the first is vaccination with isolation of diseased and in-contact animals, and the slaughter policy is the second method.

In order to understand the principles of vaccination against foot-and-mouth disease, it is necessary to realise that three main strains of foot-and-mouth virus are recognised; these are known as the 'O', 'A' and 'C' strains. There also exist variants of each of these strains. Animals may become infected with all three main types, one after the other and in quick succession, since infection by one strain, though this may lead to immunity against that particular strain, does not protect against the others.

Vaccines can be prepared against all three strains and their variants, and it is possible to protect a herd of cattle or swine, or a flock of sheep or goats against one strain (with what is called a monovalent vaccine), or against all three strains and some of their known variants with a polyvalent vaccine. The immunity conferred by such vaccines lasts only for about six months so that vaccination

must be repeated twice yearly to be effective; more important, the vaccine must be directed against the particular strain of virus causing the epidemic or else it is useless. In those countries where vaccination is practised, infected and in-contact animals are isolated in order to prevent further spread of the disease.

The slaughter policy means just what it says. Whenever foot-and-mouth disease is confirmed on a farm, all cloven-hooved animals on that farm are slaughtered. In this country the farmer is compensated for the loss of the number of animals slaughtered. But there can be no compensation for the work and skill and knowledge which have gone into the production of a valuable strain of first-class animals, which may have taken a lifetime to perfect, nor for the very real grief caused to those who have tended the animals with care and affection over the years.

The slaughter policy also entails drastic quarantine measures applied not only to the affected farm but to all farms within a radius of several miles. All the animals are restricted to their stables or byres, dogs and cats are kept in, and even the farm personnel are allowed to move only with permission and after thorough disinfection.

Horses and other solipeds (a soliped is an ungulate with an undivided hoof) have a completely effective natural immunity to foot-and-mouth disease—in fact, it is impossible to infect horses with the virus, while birds, too, are naturally resistant. Cloven-hooved animals, on the other hand, have very little natural immunity, and practically every animal in the herd becomes infected to a greater or lesser degree during an epidemic. These animals are dependent, therefore, for protection on either acquired or artificial immunity. Acquired immunity is the resistance acquired by an animal to a disease, following an attack of that disease; artificial immunity is conferred on an animal by the injection of vaccines or protective anti-sera.

It follows, therefore, that cloven-hooved animals in this country have practically no immunity to foot-and-mouth disease, since they are denied the protection of vaccines, and they are not allowed to survive natural infections. *This is one of the drawbacks of the slaughter policy, but the dangers inherent in the vaccination policy are much greater.*

Whether a country chooses the vaccination or the slaughter policy will depend on the prevailing circumstances. In Germany, for example, the disease is so rife that it would be economically impossible to slaughter all the infected animals and their contacts. In countries where the disease is not endemic, that is when there are intervals of months or even years between outbreaks, it is possible to control the infection by slaughter. Countries at present using the slaughter policy are Eire and Northern Ireland, Norway and Sweden, the U.S.A., Canada and South Africa.

The slaughter policy is much superior to vaccination from an economic point of view. This can be illustrated by the fact that in Germany (where vaccination and isolation are practised) during the 1937–8 epidemic, the loss to the country was estimated at £83 million, whereas in this country the average compensation paid out to farmers per annum over the years 1941–51 was about £222,000. Then again vaccines are very expensive to produce, and the twice-yearly inoculation of the entire cloven-hooved population of this country would involve an expenditure in manpower and money which we certainly could not afford, and which would be vastly in excess of the aforementioned £222,000. Moreover, vaccination may be sufficient in some animals to prevent the formation of gross lesions, but not to prevent the multiplication of virus in the body. Such animals become a grave source of danger to unvaccinated young stock.

The source of the infection in the present epidemic in this country is the subject of much debate. There are those who say that migratory birds bring the virus on their feathers and claws across the Channel, and who point out that outbreaks follow the routes of the autumn and spring migrations. But in the U.S.A. which has been free of foot-and-mouth disease since 1929, are there not birds migrating from Mexico and countries in South America where the disease is endemic? The freedom in the U.S.A. is more likely to be explained by the rigid exclusion of fresh meat, fresh hides and fresh offal from countries in which the disease is known to exist. If the meat has been treated in such a way as to render the virus harmless, then it may be imported. The processes involved in canning and smoking meat, for example, kill the virus. It is well known that the carcasses of animals slaughtered during the infective stages of the disease remain infective for several weeks even though the meat has been chilled or frozen. This fact provides one of the several reasons why it is most important that garbage, especially that containing meat scraps, should be sterilised by boiling before being fed to swine. In Great Britain it is not possible to forbid the import of meat from infected areas of South America or the European continent unless we are to become a race of near-vegetarians.

It is clear from the foregoing that control of foot-and-mouth disease in this country is not simply a matter of national concern but that it must be tackled on an international scale. The Organisation for European Economic Cooperation has already drawn up a report on the Control of Livestock Diseases in European Countries. This report outlines a programme for action against five major diseases of domestic animals, including foot-and-mouth, which it describes as one of the greatest limiting factors in the supplies of meat, dairy products, hides and wool. International cooperation on these lines is not unknown. There is, for example, the collaboration between the Mexican and the United States Governments in the great outbreak in Mexico in 1946, and the cooperation proved to be of mutual advantage to both countries.

Although the problem for Europe is more complicated here, involving as it does so many governments, it is still capable of solution, if all the countries concerned work together towards the common objective.

Electric Eels

RICHARD KEYNES, M.A., Ph.D.

IF you go to the New York Aquarium you will find one occupant that advertises its presence by providing, from its own resources, the current to light up a neon sign outside its tank. This is an electric eel. You can see one in the London Aquarium too, though there it does not behave with such blatant immodesty. Strictly speaking, the electric eel is not a true eel, but a kind of fish called a *gymnotid*. It is eel-like in shape, with a blunt head, dark-brown back, orange belly, and a slightly menacing air about it. It comes from the muddy waters of the Amazon and the Orinoco, in South America. The great explorer Humboldt once asked some Indians to catch electric eels for him, which they did by driving a herd of wild horses into a shallow part of the river, so that the terrified eels would exhaust their electricity in the frantic struggle that followed, and could then be speared with impunity—even by the most nervous fisherman. Nowadays with the invention of insulating rubber gloves it is comparatively safe to catch these eels alive and then transport them to other parts of the world for the public to wonder at and scientists to investigate.

The first suggestion that the paralysing effect produced by these creatures, and by certain other fishes, was due to an electric discharge was made at least as long ago as 1773, by an English scientist named John Walsh. But it took the concerted efforts of a whole galaxy of famous scientists—Cavendish, Franklin, Volta, Davy and Faraday—spread over the next sixty years, to prove the point up to the hilt. Recently, electric eels have been studied chiefly in New York and in Professor Chagas's laboratory in Rio de Janeiro. I owe my own interest in them to a very welcome invitation to spend last summer working in Rio with Brazilian scientists.*

The eel's electric organ is an astonishing adaptation. All its guts are crowded into the first fifth of its length, leaving the remaining four-fifths almost entirely filled by a jelly-like mass of electroplates, as they are called, the minute cells of which the electric organ is built. Over half the total weight of the eel is just electric organ. When you realise that a large eel may be seven feet long and as thick as a man's thigh, you will understand what a formidable creature it is. If the eel is taken out of the water, it can produce a shock of no less than five hundred volts—about twice the voltage of the ordinary domestic power supply. In the water it is partly short-circuited, and then only gives two hundred and fifty volts. It can generate a current of about half an ampere, so that its peak power output is over a hundred watts—enough to run a large electric light bulb. But before someone thinks of the obvious joke about mobile power stations, I must hasten to add that it is not capable of giving this huge power for very long. Its discharge normally consists of a group of five pulses of current, during which the eel's head momentarily becomes positive with respect to its tail. Each pulse lasts for only three-thousandths of a second, and the groups are repeated perhaps three or four times a second.

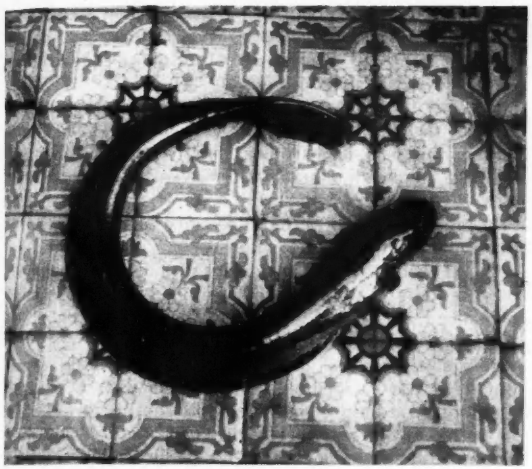
As the pulses are so short, the average power output over a period of a few seconds works out at only about five watts, and over longer times it is less still. This may seem to detract from the performance of the eel, but in fact its stunning effect would not be much increased if it could produce more sustained shocks. A series of very short but very powerful shocks is the most economical arrangement it could have adopted.

Now how is all this power generated? You will remember that I said that the electric organ is built up of a large number of little cells called electroplates. These are stacked up in columns of some three or four thousand cells stretching from the eel's head to its tail, and they discharge in such a way that although each electroplate only gives just over a seventh of a volt, their effects all add together, making up the figure of five hundred volts that I quoted a moment ago. An electrician would say that the electroplates are connected in series. This much has been known for some time, and it is really fairly obvious from the anatomy of the animal. Now we are beginning to find out in detail how the individual electroplates work, and this is what I studied in Rio. Quite likely you may not realise that every time one of your own muscles contracts, a small electrical charge, again about a seventh of a volt, sweeps quickly along each fibre of the muscle. The eel's electroplates are simply rather peculiar muscle fibres, which have been most ingeniously modified so that they have lost the ability to contract, while the electrical changes in neighbouring fibres add together, which they do not do in an ordinary muscle. In a muscle the electrical changes are caused by the movement of ions—the charged atoms of sodium, potassium and other elements that are present in all living tissues. It seems likely that similar ionic movements are the primary source of energy in the discharge of the electroplates, which might therefore be regarded as tiny wet batteries.

There is nothing new in the idea that the electric organ is derived from muscle, although most of the modern textbooks give a slightly different description of the operation of an electroplate. In some of the other electric fishes, such as the *Torpedo* or electric ray, which is found in the Atlantic and the Mediterranean, the development of the electric organ has been followed in very young specimens, and the various stages in the transformation of a muscle fibre into an electroplate have been traced. Unfortunately, no one has ever seen really young electric eels, because virtually nothing is known about their breeding habits, but I think it is fairly safe to assume that in their case the development of the electric organ is similar. Nevertheless, there is one important difference between the two kinds of fish, which is that entirely different muscles are involved.

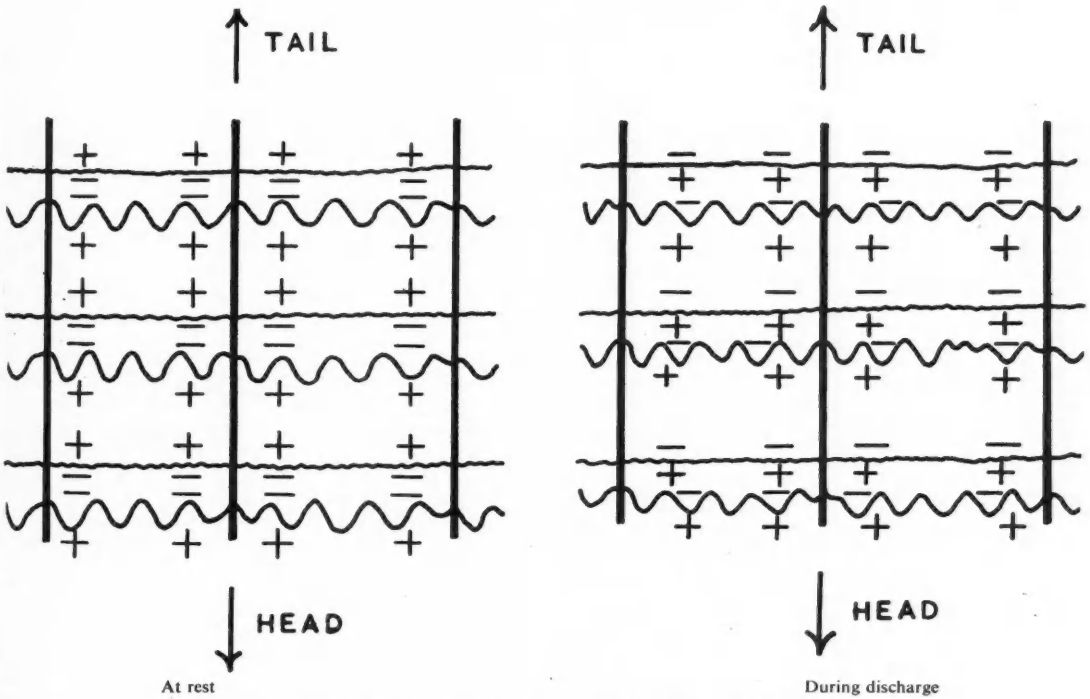
In the *Torpedo* one of the muscles which normally moves the gills has been adapted, while in the eel one of the tail muscles has turned into the electric organ. Yet another electric fish, popularly called the Star-Gazer, has electric organs developed from its eye muscles, while the electric cat-fish of the Nile apparently did not start from muscle at all, but developed its electric organ from glands in the skin. So the electric organ must have evolved quite independently

* This visit was arranged through the Anglo-Brazilian Society. The observations described here were made in collaboration with Dr. Hiss Martins-Ferreira.



A medium-sized specimen of the Electric Eel, *Electrophorus electricus* L.

Removing an eel from the tank in Professor Chagas's laboratory.



The mechanism by which the electric eel produces its discharge. In the resting state, there is no net voltage across the electroplates, because the potential differences across their two faces are equal and opposed. When a nerve impulse reaches the side of the electroplate facing the tail of the eel, the potential across it is reversed for about two milliseconds, so that the +'s and −'s are momentarily all in series. Each electroplate then contributes about 0·15 volts towards the whole discharge.

in all these species—a striking example of what is known as parallel evolution. It is also possible that the electric organ was first evolved rather early in the history of the world, because reconstructions of one of the most primitive fossil fishes, a kind of cephalaspid, have shown that it had an organ that certainly looks remarkably like the electric organ of *Torpedo*.

The release of the shocks is controlled by the eel's brain, through nerves connected to every electroplate. One fascinating problem for the physiologist is to discover how it is that the whole electric organ discharges at once, when one might have expected that the nervous impulses that trigger it would arrive at the electroplates closest to the brain appreciably earlier than at those in the tail of the eel. This question has been studied in Rio by Professor Fessard, of Paris. He has found that the nervous system incorporates a delay device, probably in the spinal cord, which compensates almost exactly for differences in nervous conduction time, so that impulses going to the front of the electric organ are delayed on the way until in the end they arrive at the same time as those that have to travel several feet before reaching their destination.

You have probably been wondering just what the eel uses its electric discharge for. Part of the answer is clear. When a frog is dropped into the tank of eels in Rio it does not survive very long. As soon as one of the eels comes close enough, the frog gives one convulsive kick and then stays stretched out, motionless. A moment later it has been engulfed whole. Although we know much more about how the electric organ works than about the way electric fishes live, there is no doubt that those that have large electric organs do use them for offensive purposes—to stun their prey. It has been recorded that a *Torpedo* caught off the English coast had in its stomach a five-pound salmon, which showed no sign of any tooth marks, and must have been first stunned and then swallowed whole.

Normally, these electric fishes only discharge their shocks when they need to—that is, when they are within range of a prospective meal. But they also tend to discharge when alarmed in any way, or when their skin is touched. So taking an electric eel out of the tank is a rather hazardous procedure best delegated to someone else. Their behaviour has been known to mankind for thousands of years, so that electric-shock therapy is a much less modern form of medical treatment than possibly many present-day doctors suppose.

Roman doctors used to treat gout by making their patients stand on a *Torpedo* until they were numbed to the knees, and they even tried to cure chronic headaches by wrapping a live *Torpedo* round the forehead. South American Indians are said to use electric eels in a similar way, to treat cases of paralysis.

But this is not quite the whole story. One of the odd things about electric eels is that they are blind. They do have eyes, but they are cloudy and degenerated; in the adult animals the eyes are certainly useless. This degeneration may have occurred because they live in such dark and dirty water that eyes would in any case be of no value to them. And yet if you watch the eels in a tank, they swim round and round without ever bumping into the sides.

How do they know where the sides are? The answer to this question was provided by an important discovery which was made by Dr. H. W. Lissmann in Cambridge last year. He noticed that a West African fish called *Gymnarchus* could steer itself extraordinarily well backwards, evidently without seeing where it was going. He found that it was doing this with the aid of what I might describe loosely as a crude *radar system*, transmitting electric pulses from a small electric organ in its tail. An American scientist had previously suggested that electric eels were equipped with a direction-finding system of some sort, and so we repeated some of Dr. Lissmann's experiments on an electric eel in Rio.

If we put two vertical bare wires in the water, separated by about a foot, the eel would swim past without seeming to notice them. But if the ends of the wires were touched together outside the water just as the eel was passing, it would give a sudden jump, and move backwards to find out what was happening. In the same way, it paid no attention to a loop of insulated wire dipped in the water alongside it, but reacted violently to a loop of bare wire. When we connected a cathode-ray oscilloscope to our two wires, to see whether the eel was sending out any pulses, we found that a stationary eel did not transmit at all, but that as soon as it began to move it sent out pulses at a rate of about one a second, speeding up to about twenty pulses a second when it was really intrigued by some object in the water. These pulses were only about a fortieth as large as those recorded when the eel was prodded to make it give its main discharge, and were probably being generated by a small, special part of the electric organ.

So the second function of the electric organ is to act as the transmitter for a direction-finding system, which enables the eel to locate anything that is a much better or a much worse conductor of electricity than fresh water. It can thus detect the presence of another fish, which would be a relatively good conductor, or of an obstacle like the wall of the tank, which would be a bad one. In fishing for eels you need no bait—the metal of the hook is all that is necessary. We do not yet know how the receiving end of the system works, nor, indeed, what or where the detectors are. As a physiologist I find it rather exciting that a new type of sensory receptor should still remain to be discovered, and this is a most interesting field for future research.

It has often puzzled zoologists to know how the electric organ of the eel could have evolved, since it would apparently have had no survival value until it had already grown rather large. Dr. Lissmann has pointed out that small electric organs used for direction-finding may provide an intermediate evolutionary step. There is, in fact, another South American fish closely related to the electric eel, that only has a very small electric organ.

There are probably other questions about electric eels which will occur to you, and which I do not expect could be answered. For instance, what happens when one eel quarrels with another eel? And why is it that an eel does not electrocute itself every time it discharges? The eel has certainly succeeded in insulating its nervous system against its own and its brethren's shocks, for in the tank they do not seem to affect one another at all. But it is not clear how this has been achieved.

(This article is the substance of a "Science Survey" *talk, broadcast on the Home Service on March* 27.)

The Search for New Antibiotics

AT THE M.R.C. RESEARCH STATION AT CLEVEDON

SINCE the days when Sir Howard Florey and his team at Oxford finally established the curative powers of penicillin, Sir Alexander Fleming's mould extract, five other powerful antibiotics have been discovered. They are streptomycin, chloromycetin, aureomycin, terramycin and neomycin.

All five were discovered and developed in the United States. They have brought great prestige to American science and have earned huge sums of money for the U.S. economy. Streptomycin, chloromycetin and aureomycin are now being made in Britain and other countries either by U.S. firms or under licence from them. A factory to make terramycin is shortly to be built here.

The U.S. scientists have been lucky, for the search for new antibiotics is a chancy business, being largely dependent on empirical methods. But the main reason for their success is the scale on which the search for germ-killing derivatives of living organisms has been pursued.

Having cashed in on penicillin by developing the 'deep fermentation' mass-production methods, U.S. drug companies quickly realised that there was big money to be made from antibiotics. So concerns like Lederle, Merck and Pfizer put up large sums to give big teams of first-rate men every facility for repeating Fleming's accidental success.

These scientists patiently examined thousands of soil samples for likely moulds, and the result was the discovery of four out of the five antibiotics mentioned above. Only one of the five, streptomycin, was discovered in a university laboratory. And in the case of this drug U.S. business men came in quickly with financial help. Firms which now make streptomycin gave nearly a million dollars towards its early clinical trials. The extent to which their investments have paid off illustrates the value of a policy of enlightened self-interest in research.

Meanwhile, in Britain, the pharmaceutical firms put most of their money and effort into mass-producing the antibiotics discovered in the U.S.A. The laboratory space and skill devoted to fundamental research on antibiotics have been small compared with the American enterprise.

With a view to improving Britain's position in the search for new germ-killing drugs the Medical Research Council has recently set up an Antibiotics Research Station at Clevedon, in Somerset, a small coastal town which lies twelve miles to the west of Bristol. The arrangements there are admirable. A team of five scientists, headed by a vigorous and able director, is systematically working through two groups of fungi which show considerable promise. The research station is accommodated in an old private house, and in an annexe built in the large back garden. This annexe houses a pilot plant which can be used to prepare large quantities of an antibiotic after it has been produced on a small scale in the laboratory. This pilot plant came into being during the war, being put up at the instigation of Surgeon Vice-Admiral Sir Sheldon Dudley, then Medical Director-General of the Navy. This plant was used for the small-scale production of penicillin in flasks. (For the Navy to set up its own separate penicillin plant was in the best naval traditions; the Navy has near'y always aimed to be as self-sufficient as possible, and by choice it relies as little as possible on other Government departments; in this case, it is said that as soon as the Navy learned that the responsibility for making penicillin had been imposed on the Ministry of Supply, it decided to start its own penicillin plant!)

Eventually the Navy's penicillin project proved redundant. After the war the whole set-up at Clevedon was sold to the Distillers Co. who used it as a pilot plant for the production of streptomycin. The company decided to close the place down nearly three years ago, but fortunately the Medical Research Council stepped in and rented the place for a trial period of one year. Results proved so promising that the M.R.C. acquired it later for the nation.

The present director, Mr. Brendan Kelly, is a former employee of the Distillers Co. with wide experience of antibiotic production. Mr. Kelly is a mathematician, a fact which may seem surprising until one realises that statisticians have an important role to play in the preliminary assessments which determine whether a new antibiotic is showing sufficient promise to warrant further work.

Fungi from two main sources are now being studied at Clevedon. The first of these is the large collection of Basidiomycetes (i.e. the group of fungi to which mushrooms and toadstools belong), collected and cultured by Professor William Wilkins who also carried out preliminary tests on them for antibiotic activity. This collection includes the honey agaric (*Armillaria mellea*), the shaggy cap (*Coprinus comatus*) and several species of bracket fungi which grow on trees (e.g. *Polyporus betulinus*, the chalky-white fungus which parasitises silver birch).

The second source is a series of assorted fungi sent in by Dr. R. Green from the Institute for Medical Research, Kuala Lumpur, Malaya. These are mainly Actinomycetes. (Streptomycin derives from a member of the Actinomycetes, called *Streptomyces griseus*.) They are mostly soil moulds, but one at least is a fungus isolated from the alimentary canal of a white ant.

Other likely fungi are examined from time to time and so are any bacteria which seem to show promising antibiotic activity.

The fungi are cultured in bottles by Miss Pamela Boyd, a mycologist. It may perhaps seem surprising that toadstools and bracket fungi can be cultured on nutrient media, but for antibiotic preparation only the vegetative part—the weft of threads, or *mycelium* as it is called—need be grown, though were it necessary to have the fruiting stage, fungi could be grown to that stage of maturity *in vitro*. There would be no purpose in attempting to grow the fruiting bodies.

All manner of potential food sources are used to devise the best nutrient mixtures for growing the moulds. They include, for instance, such materials as corn-steep liquor, marmite, an extract of the yeast used in making Guinness, and fish meal.

When a new fungus has been successfully cultured, the liquid on which it has been growing can be tested for its

Miss Boyd, the research station's mycologist, examines a culture of a species of basidiomycete, which shows antibiotic activity.

activity against bacteria, for the antibiotics invariably diffuse out of the weft of mould into the nutrient medium. The liquid is tested against thirty-six strains of bacteria, including those responsible for anthrax, food poisoning, typhoid, blood poisoning, plague and tuberculosis.

The chief concern of the Clevedon scientists is to find antibiotics which may prove of value in the treatment of T.B., but activity against any important pathogenic organism is noted and can be followed up afterwards.

Any fungus which shows up in test-tube experiments as a promising source of an antibiotic principle is passed on to Mr. G. A. Miller for further development. He has at his disposal equipment for devising the most suitable methods of growing substantial quantities of selected moulds in large flasks. His assignment is to provide enough of any chosen antibiotic for clinical trials on animals and later on human subjects. At the same time he tries to assess the possibilities of making the drug commercially.

Careful control of cultural conditions is most important when one is dealing with organisms that produce antibiotics; the yield of the antibiotic varies enormously with the different conditions under which the organism can be grown. With this in mind, there are available at Clevedon several large chambers which can be thermostatically controlled at any desired growing temperature. And there is an electric power-driven system for keeping the mould cultures continuously stirred and aerated.

If endeavours to grow the particular antibiotic-producing organism succeed, the antibiotic is then passed to Mr. Clifford Hale, a biochemist whose job is to devise methods of extracting the active principle from the crude 'brew'.

When an antibiotic survives all these preliminary stages it is passed to the Sir William Dunn School of Pathology at Oxford where clinical trials are organised by the director, Sir Howard Florey. (As a member of the Medical Research Council, Sir Howard also keeps a fatherly eye on the Clevedon laboratories.)

Three times since the M.R.C. started work at Clevedon the scientists have had their hopes raised and dashed. In 1949 they began to work on cephalosporins—a group of antibiotics isolated from a species of fungus called *Cephalosporium acremonium*. The strain of fungus concerned had been isolated from the sea near a sewage outfall. Laboratory tests *in vitro* showed activity against salmonella and also against the organisms causing cholera, relapsing fever, anthrax and plague. Unfortunately this antibiotic proved to be completely inactive when injected into a living body.

Next came micrococcin, an anti-bacterial substance isolated from a strain of the germ *Micrococcus* by Dr. T. L. Su at Oxford University.

When thoroughly investigated at Clevedon, micrococcin passed all the preliminary tests, and it seemed to be particularly active against T.B. germs *in vitro*, but for a quite unexpected reason it failed when injected into living tissues. The micrococcin was so insoluble in body fluids it could not be sufficiently dispersed in the tissues to counteract a widespread T.B. infection.

From a fungus found in the stomach of a Malayan white ant the scientists isolated a powerful antibiotic which they called actitriin. This, too, looked like a winner in the first *in vitro* tests, but unfortunately it proved to be far too toxic to be used on human patients.

The Medical Research Council is most anxious to avoid arousing premature hopes, but no one can visit Clevedon without being impressed by the enthusiasm of the scientists who work there. At the same time one is struck with the almost pitifully small scale on which the whole project is planned. Comparison with the Supply Ministry's huge set-up on Salisbury Plain where antibiotics against germ-warfare attack are being developed automatically springs to mind. Though I have not been inside the Microbiological Research Department at Porton, I have talked to many scientists and military men who have. I have gained the impression that the scale of the work there and the lavishness of the equipment and laboratories are without parallel in Britain. Considering the state of world politics, nobody in his right senses doubts the necessity for this type of defence work at Porton. But the disparity between the facilities for research provided at Clevedon and those provided at Porton seems to be out of all reasonable proportion.

CHAPMAN PINCHER.

Progress in Air Archaeology

J. S. P. BRADFORD
Pitt Rivers Museum, University of Oxford

RECENT years have seen immense strides in the application of air photography to the study of man. The First World War hastened this process, and the Second made it still more effective. Technical developments which were prompted by military needs have since proved of outstanding importance for peace-time research, as has happened in so many other fields. Summing up the situation as a whole, one may say that it has proved possible, under suitable circumstances, to rediscover entire ancient landscapes, complete with cities, villages and fields, while many unexpected details have been rendered visible. It must be emphasised that air photographs, when systematically taken and interpreted, and administered as a library, constitute a new form of 'document' or 'source', and thus an indispensable type of public record. Archaeology, anthropology, history, geography and all environmental studies have benefited directly from this application of science to the service of the humanities.

Indeed, it is recognised that the rate of discovery has quite outpaced the full reconnaissance, let alone excavation, of all the important sites found or the solution of the problems of interest for so many periods that they raise. It is now possible, with a planned programme of air photography and interpretation, combined with economical test-excavation at selected points, to cram the equivalent of a lifetime's work into the span of a year or two. Nor has the quality of the achievement been lessened thereby. This field of discovery has aroused devoted enthusiasm in its adherents, and British archaeology, led by men like O. G. S. Crawford and the late Major Allen, has maintained a pre-eminent position internationally in the practice of this technique.

It is not altogether surprising that discoveries on so large a scale and so far-reaching in scope should be much more slowly assimilated into general books and common knowledge. Recent examples include Williams-Hunt's aerial plans of several hundred ancient towns and settlements in South-east Asia (see Fig. 4); the finding by Poidebard in Syria, and by Baradez in Algeria, of whole systems of Roman frontier fortifications; Schmidt's great work of air survey in Persia; my own discoveries in Italy (see Figs. 2 and 3) and other Mediterranean lands; and Dr. St. Joseph's results in this country. Later I shall try to give, in briefest outline, some idea of the fundamental nature of the progress achieved in such diverse areas by systematic campaigns of air photography.

But in order to appreciate scope and scale, and potentialities for the future, we must begin with the means. From the start, a twofold use is clear. First is that of recording, planning, and demonstrating in a new and graphic manner, ancient sites already largely known on the ground, in relation to their setting. The second and more important is the discovery of new sites themselves. Both oblique and vertical air photographs are employed, but each has a special function. The former are easier for the amateur to take and interpret at first, but the latter have the supreme advantage that a scale can be calculated as readily as for a map, so that measurements of objects on the ground can be made from them. A very simple formula is sufficient:

$$\text{Scale} = \frac{F}{H \times 12},$$

where F is the focal length of the camera lens in inches and H is the flying height in feet. Alternatively

$$\text{Scale} = \frac{D}{d} \times \text{map scale},$$

where D equals the distance between two points on the photograph and d is the distance between the same two points on the map. It is best to choose three sets of such measurements and to take their average if the latter method is used.

It will be useful first to give some indications of methods that have proved successful for amateur use in England as distinct from the specialised equipment of aircraft with built-in cameras used by national air forces. For general purposes an air camera of 6- to 8-inch focal length with wide-angled lens is very suitable. Ex-R.A.F. cameras of excellent performance and of this type were available cheaply after the recent war, and several museums purchased them. Those giving a negative about 5½ inches square are useful, since archaeological detail is sufficiently clear on the contact prints. Some of the best results are obtainable from flying heights of 1200–2000 feet. A small monoplane of high-wing type, like the Fairchild, is the best choice.

The following photographic factors gave good results on a sunny day of moderate visibility:

f/8 1/300 sec. 5-inch F.L. lens.
f/5·6 1/300 sec. 8-inch F.L. lens.
Film: Super XX Kodak.
Filter: Factor No. 4, yellow.

Such factors would have to be adapted to suit slower films like Panatomic, and towards the end of the day the aperture should be increased. Spools of roll-film of 50–100 exposures make it unnecessary to reload the camera in the air. Even a Leica ground camera can give tolerable results initially for record purposes (with enlargements), but naturally such photographs do not give the fullest definition of detail. For reliable vertical photography the camera must be mounted in the aircraft itself and sited through a glass or Perspex panel in the floor, although even with a hand-held camera it is possible to obtain good 'near-verticals' by tightly banking the aeroplane (e.g. Fig. 1). In all such amateur work a team of three is highly desirable. This includes pilot, cameraman and an observer to pinpoint the sites on the map as they are found and photographed.

There are many occasions when such relatively simple methods yield a rich crop of individual discoveries. But for the intensive study of a region, sometimes in terms of huge areas, this is not enough. Continuous strips of consecutive vertical photographs, each with a common overlap of 60% with the next to make stereoscopic

examination possible, then become essential, and fitted cameras with automatic exposures are required. The procedure does not materially differ from that in regular use for air survey and mapping, while for the photo interpretation, a simple pocket stereoscope magnifying two or three times is quite sufficient. With this simple instrument, examining the area common to each of a pair of consecutive overlapping photographs, one can see all ground features in relief in their relative height and depth. This is often of extreme importance in studying ancient earthworks (perhaps much flattened), e.g. tumuli, mounds indicating buildings in ancient ruined cities, the course of old roads, defensive ramparts and ditches, etc. With experience, small but important subtleties of slope and shape can be distinguished in this way when a ground examination alone might easily pass them by. It is not too much to say that under the stereoscope, the landscape, whether 'buried' or existing, takes on a living quality so that one can move about it in thought and picture it as at eye-level, even if one has never set foot on the ground. In work of this kind better results are obtained at heights over 5000 feet, but the magnification of the stereoscope's lenses helps to make up for the smaller photographic scale. With good visibility, especially as experienced in Italy, the Near East, etc., good photographs showing details of large archaeological sites can be taken from a height of 3 miles (Figs. 2, 3 and 4 are enlargements from these), and elaborate and thorough interpretation can be done from photographs with scales of 1:10,000 or 1:12,000. Among archaeologists there is still, perhaps, a tendency at the present time to rely too much on low-level obliques, and single hand-held verticals. They are easier to take, and also cheaper, but no sensible person who is accustomed to working with sequences of vertical photographs, which give continuous 'coverage' over a wide area and make stereoscopic examination possible, would ever wish for any other method as a regular basis. In exploring from the air such relatively unknown and inaccessible regions as Siam and Iraq, vertical photography in continuous strips is indispensable. But in more intimate and better studied landscapes of European states, hand-held air cameras can be most effective.

An Activity for Amateurs

Aerial research and discovery are still in a stage when there are very rewarding opportunities for well-thought-out amateur effort. Although there has been a complete vertical air survey of Britain by the R.A.F., great quantities of ancient sites of the first importance quite certainly await discovery from the air. The R.A.F. survey naturally could not be carried out regularly at the seasons suited for the appearance of buried archaeological sites as crop-markings, soil-markings, etc. The brilliant achievement of the late Major Allen, who revealed, within the space of six or seven years, so many prehistoric and Roman settlements, farms and field-systems in southern England, put professional archaeology once more in lasting debt to a skilled amateur. Fig. 1 shows an example of his work. Yet so numerous are the finds to be made that even in Oxfordshire, which Major Allen combed, recent flights have added still more sites to the list. Members of flying clubs and their friends, in particular, could follow his example and build up teams to advance aerial research and discovery. If the planning, and their observation, photography and interpretation were done systematically, they could be almost certain of making discoveries of major importance in most parts of the country.

The interpretation of the nature and details of archaeological sites from air photographs naturally requires an experienced knowledge of the kinds of structural remains that may be expected from various types of site, e.g. the regular angular outlines of Roman fields and farm-yards; the circular or concentric ring-ditches of British Bronze Age burial and ritual sites; or the *tells* or raised mounds, formed by successive rebuildings, that mark the sites of ancient towns in the Near East. The differential growth, in quantity, quality, degree of maturity or colour, shown by crops, grass, flowering weeds and vegetation in various forms, often disclose the outline of walls, ditches, post-holes and any structural features beneath, whose presence close to the soil-surface has advanced or retarded natural growth.

Fig. 1, a low vertical view by the late Major Allen, gives a magnificent example of this phenomenon, seen in a cornfield during July 1938 near Dorchester in Oxfordshire. It shows (from left to right) the great parallel ditches of a ceremonial site of Late Neolithic or Early Bronze Age type (perhaps as early as 1800 B.C.), a rectangular enclosure (perhaps a farm-yard) probably dating from shortly before or after the Roman Conquest, and two Bronze Age ritual circles (one having concentric ditches and a central spot suggesting a burial pit). All these were previously unknown. Such crop-markings are best seen where the topsoil is shallow and the subsoil well drained (rock, chalk, gravel), being equally clear on Wessex downlands and the prairie grasslands of South America. Soil-marks, caused by differences in the normal colour and content of the topsoil occasioned by upcast from ancient ditches, or the scattered debris of former buildings, represent another kind of tell-tale feature that often shows clearly in contrasting tones on air photographs. A low sun, and other conditions of light, will often throw into prominence earthworks (e.g. those of ancient systems of cultivation or irrigation) that otherwise would tend to be overlooked.

Forms of 'crop-marks', 'soil-marks' and 'shadow-marks' are features to be found in many countries, though regional peculiarities, of course, exist.

I refer below to the special types of site encountered in Persia, Siam, etc., and the unusual problems to be met in taking and interpreting archaeological air photographs in areas of near-desert or tropical rain-forest. But wherever the research may be carried out, the essence of interpretation lies in familiarising oneself with the appearance of all surface features from the air, not merely those of an obvious archaeological significance. In this way one gains a fuller impression of the site in its setting, and the abnormal or significant details can be swiftly distinguished from the normal traces of agricultural or industrial activities in their manifold forms. In the examination of vertical air photographs, it is also most essential to know what amount of topographical detail can be expected from photographs of large scales or of small. At one scale, small objects a few feet across can be measured precisely

with the aid of a micrometer scale and a book of photogrammetric tables; while at another scale they may become so small that they are quite beyond the range of definition imposed by the grain of the film. It all depends on the extent of the area of ground that it is desired to cover with each photograph. The scale of the vertical view is affected as much by the focal length of the camera's lens as by the flying height; thus a 36-inch lens at 30,000 feet and a 6-inch lens at 5000 feet will both give photographs of 1 : 10,000 scale (roughly 6 inches to 1 mile). For the large square units of Roman field-systems in Southern Europe this scale will do very well, and it is likewise appropriate for ancient town-plans and the course of roads. It is, in fact, surprising how much can be learnt from photographs of smaller scale, and even at a scale of 1 : 50,000 (nearly 1 inch to 1 mile) the deserted sites of ancient cities in Siam and Persia show with remarkable clarity. For detailed work on complex sites about 1 : 6000 is the optimum for vertical photographs, for the stereoscope's magnification will improve this scale two to three times.

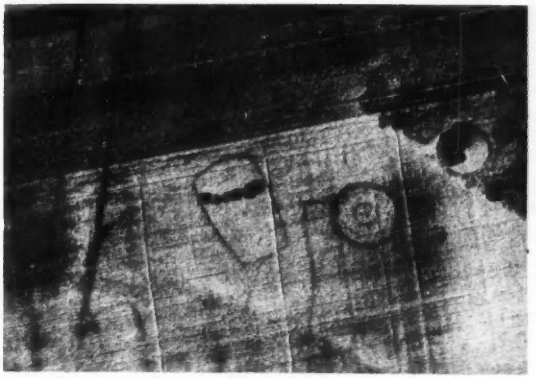


FIG. 1.—This vertical air photograph taken by the late Major Allen revealed a complex of prehistoric sites below ground level, from 'crop-markings' over them, near Dorchester-on-Thames.

Aerial Reconnaissance in Persia

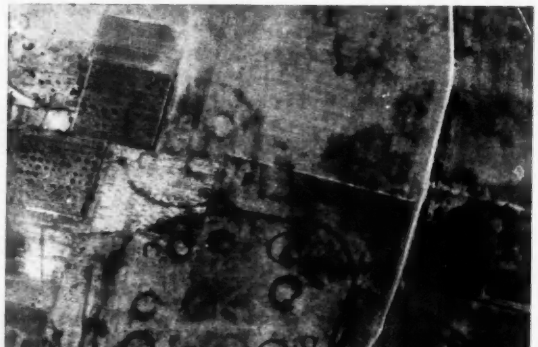
A good deal can be learnt from the experiences of Erich Schmidt, who directed archaeological air reconnaissances over Persia for the Oriental Institute of Chicago University, which he described in *Flights over Ancient Cities of Iran* (published 1940). Many fine photographs were taken of ancient city sites, some of them yielding new discoveries. Particularly impressive are those of the huge circular city of Gur in South-west Persia, over a mile across. It was a flourishing capital about 200 B.C. but has long been completely deserted. At the other end of the country, which lies close to the southern frontier of the Soviet Union at the south-east corner of the Caspian Sea, Schmidt photographed many new prehistoric settlement mounds, occasionally landing on a patch of level ground to collect surface finds of prehistoric pottery fragments which helped to date them. In the plain around ancient Persepolis they succeeded in recording aerial plans of more than 400 archaeological sites in thirteen hours.

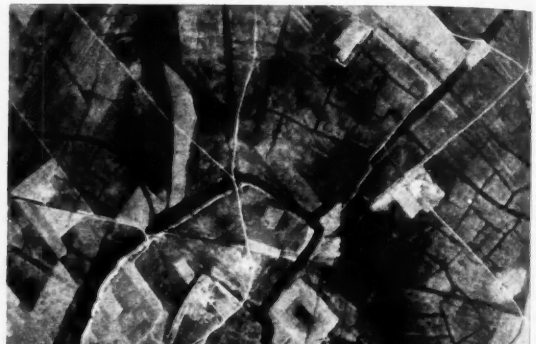
Dr. Schmidt's crew consisted of himself and his wife, a pilot and a Persian Air Force officer who was detailed to fly with them. In addition he had a mechanic to service the plane, and a technician to process the photographs. By ordinary European archaeological standards this expedition was on a lavish scale. A cabin biplane was bought, equipped with a 220-h.p. engine. Its wing tanks carried seventy gallons of petrol plus eighteen in a spare tank—a wise precaution for the Persian mountains are no place for forced landings! A special visit was made to the Zeiss factory at Jena, where a 'Fl.K.19' air camera was chosen; this, however, proved unsatisfactory as the focal length was too short, with the result that the edges of the prints were blurred. Instead, a 'Fl.K.25' was taken, with a focal length of 25 cm.—i.e. about 10 inches. (The present British F.24 camera, with interchangeable lens, is as good, if not better.)

Though preparations were elaborate, some essential preliminaries were overlooked through lack of experience. Somewhat surprisingly Dr. Schmidt remarks that the thought did not occur to them that "aerial operations, in spite of idealistic purposes, have delicate aspects, especially in the troubled countries of the Old World". There was, not unnaturally, a delay. The aircraft had been crated and dispatched, but official permission had not filtered down through the devious channels of Persian bureaucracy. Eventually the expedition agreed to leave the aircraft behind when photography was over. Another difficulty was that caused by initial lack of practice in identification and interpretation. The true significance of 'crop-markings' and 'soil-markings' was not realised at the beginning, as Dr. Schmidt admits, although both phenomena had for some time been understood and exploited by British archaeologists in particular.

But these experiments in archaeology from the air over Persia deserve special attention because of the interesting details Dr. Schmidt gives about the technical methods he used, details which are valuable to all those who plan similar reconnaissance for research purposes. As Dr. Schmidt's book is both rare and expensive I will summarise its conclusions. In default of the specially mounted, built-in cameras (with automatically timed exposures) of the types employed by the R.A.F., Dr. Schmidt's expedition had to employ simpler methods for vertical photography, and they chose the aerotopograph device. This was a suspension mechanism fixed to a hole in the floor of the aircraft and carrying the camera. A telescope, with its axis parallel to that of the camera, is attached and this shows precisely the area of ground being photographed at any given moment. Drift, from cross-winds, is corrected by a movable disc supporting the camera. By means of three screws the whole device is adjusted to a horizontal position defined by levels in the telescope and on the camera. A second exposure, giving a 60% overlap, allowed for stereoscopic examination.

The two hours after sunrise proved to be the best for photography in this region; later on in the day the earth seemed to lose much of its relief. (In Europe, early morning and late afternoon are preferred where 'shadow sites' are concerned. For 'crop-mark' sites, timing is of less importance as long as visibility is good.) The task of the observer/map reader in Dr. Schmidt's crew was to record





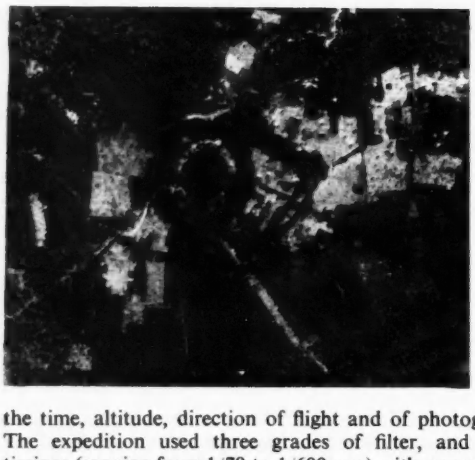


FIG. 2 (*top left*).—One of over two hundred settlements from a period centred on *c.* 2000 B.C., found from air photographs in South Italy by the author. They are disclosed by the differential growth of vegetation over them —i.e. 'crop-markings'. This site, 240 yds. across, is enclosed by a ditch and contains 14 very clear compounds. With such a plan in hand, excavation is made much easier.

FIG. 3 (*above*).—The plan of a deserted medieval village and its field-system in South Italy, first revealed in detail by this air photograph. It is also the site of a country palace of Emperor Frederic II, built *c.* 1237.

FIG. 4 (*left*).—The vertical air photograph provides, for the first time, an accurate plan of the site of the ruined city of Ban Sai in Eastern Siam, lying in jungle scrub and rice fields. The site, 1100 yds. across and enclosed by moats and ramparts, is typical of Williams-Hunt's many discoveries in this area.

the time, altitude, direction of flight and of photograph. The expedition used three grades of filter, and three timings (ranging from 1/70 to 1/600 sec.) with an aperture of 1:3·5.

Besides the air camera and its telescope, the aircraft carried maps, an iron ration of concentrated foods, a medical kit, flasks with boiled water, and a camera to be used for ground photography when the expedition landed to inspect sites of special significance. Hardly less important than the expedition's discovery of new sites was their detailed aerial mapping of sites which were already known. In fact, the expedition developed techniques which cut out a great deal of the expensive ground survey.

Some regions are more suitable by nature for archaeological discoveries from the air than are others. Over large parts of Europe, particularly Central and Eastern Europe, the division of most of the more fertile ground into innumerable thin 'strip-fields' for small peasant-holdings produces a kaleidoscopic pattern of varied cultivation, in which 'crop-markings' tend to be unintelligible. However, in one part of Southern Europe—namely in the province of Apulia in South Italy—one finds a region where conditions are perfect. In 1949–50, an expedition under my direction carried out a systematic programme of ground inspection and excavation based entirely on air photographs which had brought to light a wealth of new sites. This was the first archaeological campaign of this kind on Italian soil, which is so richly endowed with sites of all periods. We were working with air photographs taken in 1945 by Williams-Hunt and myself (mainly oblique photographs obtained with a 6-inch focal length camera, hand-held in a Fairchild high-wing monoplane) and verticals taken by the R.A.F. on routine reconnaissance practice after hostilities ended in May 1945.

The Foggia Plain, on which we concentrated, consists almost entirely of immense, unhedged, arable fields. This coastal zone, 60 by 30 miles, is virtually a miniature 'steppe'. Rock lies close to the surface, there is little rainfall, and the rolling 'sea' of corn and rough grass is already parched by the end of May or early June. Under such

conditions, 'crop-markings' appear with striking effect. When flying over one particularly good example for the first time, I almost believed for a moment that the outline of ditches and enclosures which I could see below must be due to modern agriculture. When I excavated there, some years later, these proved to belong to the Neolithic period—before 2000 B.C. In other words, we had found one of the settlements of the first farming communities in Italy.

When the photographs were carefully studied, the outlines of a sequence of several distinctive types of 'buried landscapes' could be seen. Settlements, roads, farms and field-systems were preserved below the surface. Above their ditches, etc.—though long since levelled by natural silting—the vegetation took advantage of the extra depth of soil, and in appearance (as taller, more luxuriant, greener, etc.) differed from vegetation elsewhere. Often the colour contrasts were quite dramatic, and obvious alike to the eye and on the photograph. On the ground such differences were also apparent and ancient sites were sometimes delineated in yellow, blue or white, by long-rooted flowering weeds that grew richly above them. Thus, the parallel ditches that ran along each side of a former Roman road were sometimes shown as two bright bands of colour that ran like tram-lines across pasture land.

All these sites were previously quite unknown. Although some general indications of their age could be obtained in many cases from the study of the site plans revealed by the air photographs, it was obvious that major discoveries belonging to several different periods were involved. Further investigation on the ground, particularly excavation, was called for, and detailed results of this work are now being prepared for publication, though Interim Reports have appeared (in *Antiquity*, 1949, 1950), and some general points from these are worth mentioning.

The examination of the air photographs showed me the plans of more than two hundred settlements of Neolithic type, defended by wide concentric ditches up to eight in number, and containing many smaller enclosures. One of these sites covered an area 800 × 500 yards, and over 4000 fragments of pottery were excavated from the site in fourteen days. Fig. 2 shows a particularly clear example in 'crop-mark' form, surrounded by a ditch with fourteen smaller enclosures within. The site is 240 yards across, and a similar but smaller site is adjacent. These crop-marks were photographed in May from a height of 10,000 feet, and exact measurements correct to a foot or two can be made from this vertical photograph and thence transferred to the ground. In this way, too, we have been able to piece together a network of early Roman roads extending over many miles in the same area. These intersected on a regular chess-board grid, following the Roman method used when settling new farming colonists. (The same method of settlement has been practised in recent times.) Sites of farms, vineyards, orchards and field boundaries have been located all the way along these roads. It is even possible to estimate the number of vines that were grown from the 'crop-marks' made by the regularly spaced trenches for them that had been cut down into the rock, as today. When originally laid out, this great agricultural system must have been an impressive piece of planning, but long before the Middle Ages it fell into total disuse, and it had remained unknown until the 1940s.

With the same photographs we have also been able to rediscover many features of the medieval landscape, particularly the sites of medieval villages that formerly flourished but have since been completely abandoned, so that not a building remained. Fig. 3 shows an example near Foggia. This site of San Lorenzo, divided into three parts by earth ramparts and moats, measures 800 yards in length, but no satisfactory plan previously existed. It contained an imperial hunting-lodge and court of Emperor Frederic II, built *c.* 1237. Today, there are only three poverty-stricken farms. Round its sides are clustered the roughly rectangular patterns made by the boundary ditches enclosing hitherto unknown medieval fields, surviving as 'crop-' and 'soil-marks'. Modern fields have superseded them with quite a different layout.

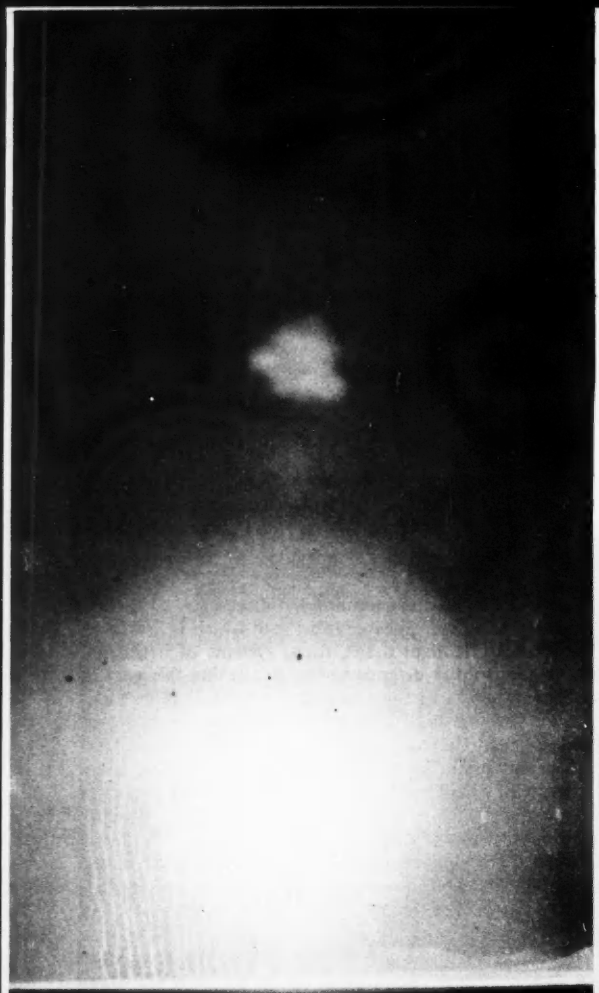
Particularly fine results have been obtained in such dry zones as the Syrian and the Algerian hinterlands, where modern cultivation has not extended to obscure earlier forms.

Colonel Baradez has recently published his extraordinarily interesting air photographs, with which he has been able to locate Roman roads, forts, systems of irrigation, etc., in the frontier defence system protecting this part of the Roman world against the Saharan tribes. Père Poidebard and Mouterde have done the same in Syria, to reveal from the air the half-buried and forgotten system of defence in depth with strong-points, on which Roman forces so long held out against the Parthians and Sassanids in desert garrisons that recall the novels of P. C. Wren!

Still more recently, R. G. Goodchild has been able, through the co-operation of the Royal Air Force, to use air photography to reconnoitre other parts of the Roman African frontier defences, this time in Cyrenaica and Tripolitania.

In terrain and conditions of an entirely different kind, in the steamy tropical scrub and rice fields of Eastern Siam, Williams-Hunt has lately made clear the potency of archaeological air photography. His discovery of many ancient cities and settlements, and the photographic plans of scores of others barely known, revolutionised knowledge of the historically rich but inaccessible region to the north of the great medieval city and temples of Angkor. Where great and powerful towns of the Mon and Khmer peoples stood 1000 years ago or more, peasants' fields and humble villages stand now. But the outline of former ramparts is preserved by the dense vegetation that clothes their banks, and ancient town moats have left their mark on the field pattern. Fig. 4 shows one of these sites, circular with a rectangular addition, 1100 yards across, still surviving in a typical tangle of scrub and paddyfields.

There is little need to emphasise the value of air photographs in recording the plan and distribution of modern tribal settlements and cultivation systems. Field work on the ground, while still of course necessary, could be immensely reduced, quickened and yet much more complete. It is time for anthropologists and ethnologists to apply to field work and research some such methods as I have outlined, for air photography undoubtedly has much to contribute to the study of living communities.



ROCKETS AID A OME

Last month brought an official announcement t site of the to be the Monte Bello Islands, off the N.-W. c of Australia. U.S.A. has perfected a mobile atomic siege-g d the releas atomic bomb under test on ing grounds

Four of these photographs are reproduced here; from left to right, these pictures show the progress of the detonation through four stages:

1. The automatic camera got this first glimpse of the blast as the bomb was set off about 3500 feet above the ground. Note concentric shock waves hurled outward as test rockets (*left foreground*) rise toward the core of the inferno leaving their smoke trails behind them.

2. The initial fireball, which had a brilliance of fifty suns, is well developed here, a split second after radio controls set the bomb off. The rockets' trails,

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AID A OMB RESEARCH

nnouncement the site of the first British atomic weapon tests is off the N.-W. of Australia. It also brought the news that the atomic siege- and the release of the latest photographs of an under test on ving grounds near Las Vegas.

duced here; from progress of the

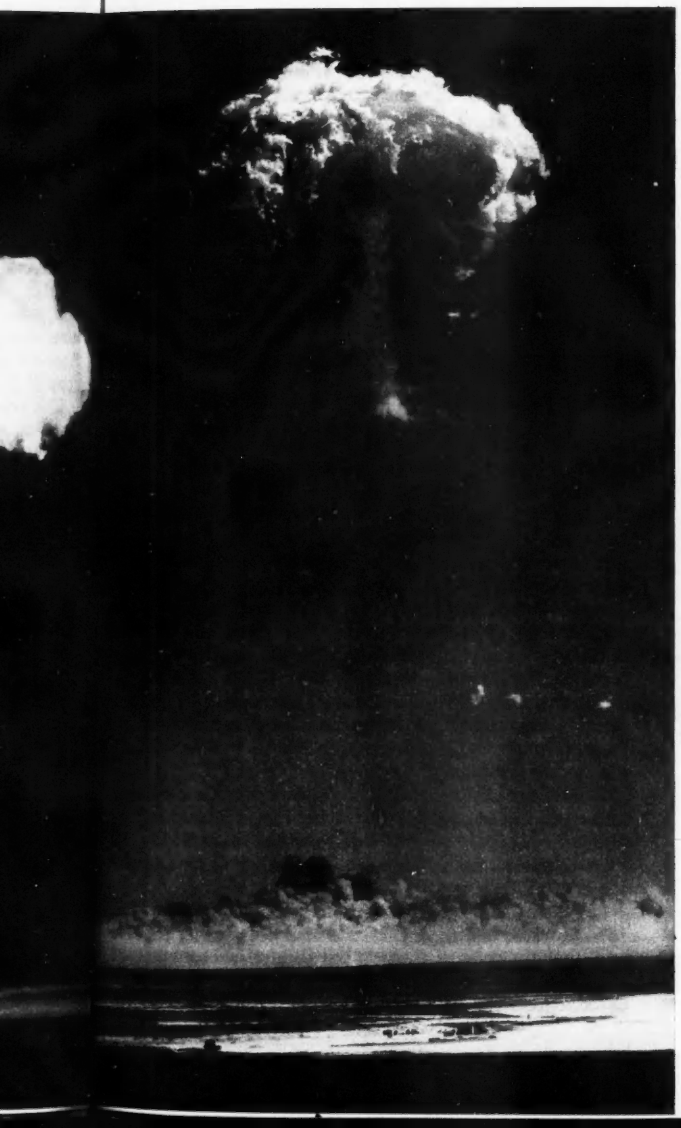
st glimpse of the 00 feet above the s hurled outward ward the core of behind them.

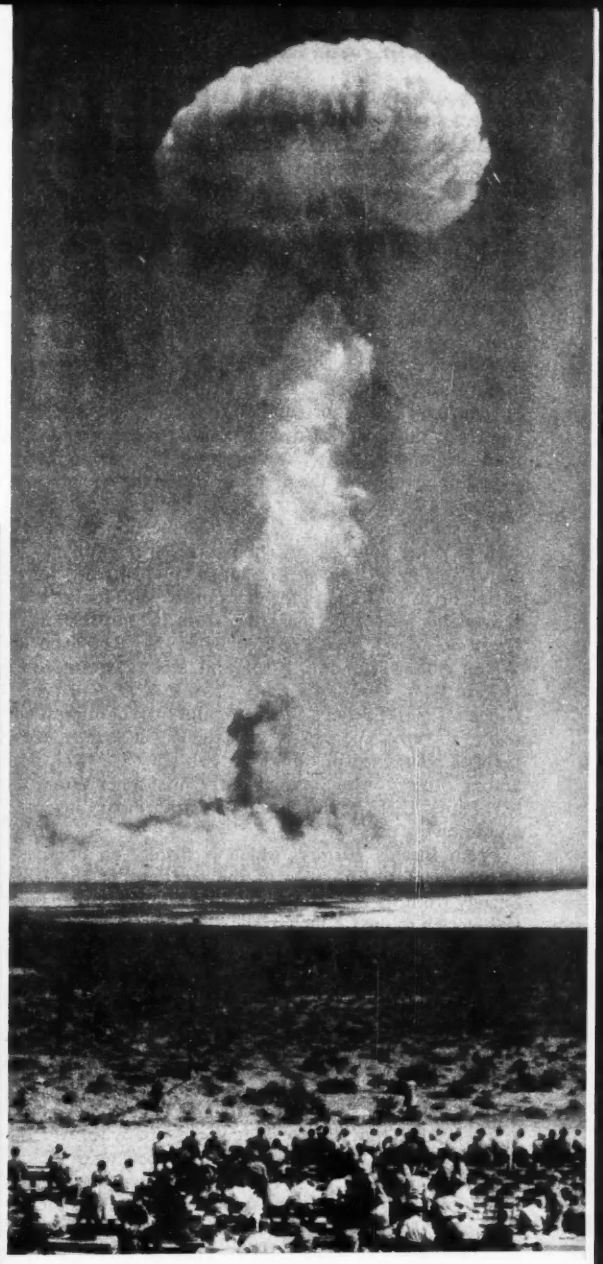
brilliance of fifty econd after radio rockets' trails.

employed to measure the bomb's potency, are already affected by the terrific force of the expanding gases.

3. The fireball here has soared to form the beginning of the mushroom, while the desert floor writhes in an immense radioactive dust cloud at least fifty miles wide. The rocket trails have faded. Small puffs at right come from other test charges for measuring the blast.

4. Here is the full flower of the mushroom as it is witnessed by hundreds of newsmen and officials. A few moments after this picture was taken, the mushroom's stem began drifting away and dissipating.





Continued from p. 149 of the last issue

Samuel Pepys, F.R.S. (1633-1703)

DOUGLAS McKIE, D.Sc., Ph.D.

In the first part of this article an account was given of the various references to the Royal Society in Pepys's *Diary* and of Pepys's connexion with the Society, of which he had been elected a Fellow on February 15, 1665. The *Diary* covers the years from 1659 to 1669 and was abandoned by Pepys on account of failing sight, which he feared might turn to blindness. It was written in cipher or rather in 'character', as 'shorthand' was then called, and is an enormous document of over 3000 quarto pages and more than one and a quarter million words.* As will be observed, it covers only the first four of the thirty-eight years of Pepys's Fellowship of the Royal Society.

For the later years of Pepys's membership we have to turn to other sources, to Thomas Birch's *History of the Royal Society of London* (London, 1756–7, 4 vols.) for the period up to 1687 and to the diary of Robert Hooke, which is available for two periods, first, from 1672 to 1680 in *The Diary of Robert Hooke* (edited by H. W. Robinson and Walter Adams, London, 1935), and, second, from 1688 to 1693 in R. T. Gunther's *Early Science in Oxford* (vol. x, Oxford, 1935). Evelyn's *Diary* contains little of interest with regard to Pepys's connexion with the Royal Society, except perhaps his record of dining on February 19, 1671, with, among others, "Mr. Surveyor Dr. Christopher Wren, and Mr. Pepys, Clerk of the Acts, two extraordinary ingenious and knowing persons".

From Birch's *History*, which is mainly an unindexed transcript of the minutes of the meetings of the Royal Society from its beginnings to 1687, it appears that Pepys was elected to the Council of the Society at the anniversary meeting of November 30, 1672, at which John Evelyn was also elected to Council and to the Secretaryship of the Society. (There is, however, some evidence that Evelyn was elected Secretary at the anniversary meeting of 1671.) Pepys was "present and sworn" at the meeting. He attended later meetings but neither at this time nor in later years, when he again served on Council, were his attendances regular; it is probable that his heavy official duties still prevented him from seeking the company for which he had expressed so strong a liking. At the meeting of Council held on October 9, 1673, he was appointed one of those who were to give thanks on the Society's behalf to the professors of Gresham College and the Mercers Company for their invitation to resume their meetings in the College; their old place of assembly from which they had been forced to move after the Great Fire.

On October 22, 1673, Pepys was found to be one of the "good paymasters" of the Society. "The council considering the necessity of securing the weekly payments for carrying on the work of the Society, and having consulted the Treasurer's book concerning the persons, that may be looked upon as good paymasters, they were found to be . . .", and there follows a list of those who had paid their subscriptions, and it includes Pepys. There was also a list of others who were in arrears, which entry is but one more indication of the financial difficulties in which the Society found itself during this early period of its history.

* The *Diary* was first transcribed in 1819 by John Smith and amounted to over 9000 quarto pages in longhand: the transcription took Smith three years to complete. About a quarter was published under the editorship of Lord Braybrooke in 1825, later editions including additional matter; an edition in 1875 by Mynors Bright included almost three-quarters of the original. The complete text, omitting some short passages, was edited by H. B. Wheatley and published in 1893–9 in a series of eight volumes.

Prince Rupert's Glass Factory

Pepys served on the Council during this year of 1672–3 and then followed a second term for 1674–5, during which, with Lord Brouncker (President) and Sir Robert Southwell, he was, as Birch records, "desired to make application to his highness prince Rupert, concerning the mischief, which his glass-house does to Chelsea college; and to suggest to the prince, that his highness may perhaps put it and the land to some good uses, if he pleases to take it to himself, and to consider the Society for it", while Sir Jonas Moore was "desired to write a letter to the prince, and to acquaint him, that the house and land of Chelsea might have been well disposed of for the benefit of the Society, if it had not been for the annoyance of the neighbouring glass-house". A 'glass-house' was, of course, a glass factory; and Prince Rupert was much interested in glass, his interest being remembered in the term "Prince Rupert's drops". As for Chelsea College, its buildings and its lands had been given by the King to the Royal Society in 1669 as a help towards their finances; there were so many claimants on Charles II's inadequate resources after the Restoration that he could neither satisfy them nor give the Royal Society a subsidy. Chelsea College, however, proved merely an additional source of anxiety to the Society; the neglected buildings were in need of repair and difficult to let and there was likely to be litigation about claims. At the moment when Pepys was a member of the deputation appointed to wait upon the Prince, the latter's 'glass-house' was a nuisance that it was desirable to abate, and the deputation was, it seems, to suggest openly to the Prince that it might be advantageous to him to acquire the property by purchase from the Society. The further history of Chelsea College, so far as the Royal Society was concerned, proved equally dismal; for, although the King resumed possession in 1682 on a promise to buy back the property for a sum of £1300, the money remained unpaid.

During this session of 1674–5, members of Council, it is interesting to note, agreed to give discourses at the meetings of the Society and Pepys undertook to present one, but there seems to be no record of his doing this or of the subject that he proposed to discuss.

Pepys served a third term as a member of Council during 1676–7, a fourth during 1681–2, and a fifth during 1684–5; and now a greater distinction fell to him in being elected President, as Birch records: "Samuel Pepys was then chosen president by twenty nine suffrages out of thirty

nine." But Samuel Pepys was not present at the meeting and some days later the secretaries were "ordered to wait upon the new president in the Society's name". Pepys attended as president for the first time at the meeting held on December 10, 1684, following his election at the meeting of December 1 (the anniversary meeting could not be held on St. Andrew's Day, because in 1684 that day fell on a Sunday). At his first meeting as president, there was news of his old acquaintance Petty, now in Ireland, and of the formation and progress of the Dublin Society, formed on the model of the parent Royal Society of London; at this meeting also, there was an interesting item from Petty: "Upon mentioning sixty three miscellaneous experiments proposed by Sir William Petty as *desiderata*, a paper containing them, which had lately been printed at Dublin, was read, and being very well approved of, was ordered to be reprinted here, in order that the members of the Society might have copies, and consider of the particulars, which they would choose to examine." And it is recorded that "The president selected those more immediately relating to navigation"—as might be expected of one who had in that year been restored to his high office as Secretary of the Admiralty. And there was other information that later became historic: "Mr. Halley gave an account, that he had lately seen Mr. Newton at Cambridge, who had shewed him a curious treatise, *De Motu*; which, upon Mr. Halley's desire, was, he said, promised to be sent to the Society to be entered upon their register."

A week later, "Sir Anthony Dean gave an account, that Sir William Petty had sent over a challenge or wager in fifteen propositions, wherein were asserted the virtues of the sluice-bottomed vessels beyond any vessels of the common make. To this challenge Sir Anthony Dean produced an answer in writing, signed by himself and Mr. Pepys: which being read, was found to contain the conditions of the several wagers, and the sums offered to be laid upon each proposition. This, Sir Anthony said, was not done out of any enmity to Sir William Petty, for whom he had a great esteem; but that Sir William might be provoked to a full proof of his assertions, which would not fail to produce many good experiments. A copy of this paper was desired, which Sir Anthony Dean promised to permit to be taken, as soon as the paper could be spared."

Again, on January 7, 1685, a letter from Petty was read at the meeting held on that day; it described his experiments on ships—Petty regarded a ship as "the greatest and noblest of all machines". The experiments had proved a failure and Petty had been greatly disappointed. A letter received from Molyneux by Aston gave fuller details: "I promised to give you an account of the performances of Sir William Petty's ship, and I am glad of an opportunity of writing to you, and serving you in any thing; but I am heartily sorry at the occasion, that at present offers itself, and would willingly be silent. But 'tis a matter so public, and of too universal concern to be concealed, and withal 'twas so probably and fairly offered at, that human frailty need not be ashamed of miscarrying therein. Sir William Petty's ship was tried this day sevennight in our harbour between Rings-End and the bar; but she performed so abominably, as if built on purpose to disappoint in the highest degree every particular, that was expected from her: she had spread but a third of the sail she was to carry, the wind did but just fill her sails, and yet she stooped so, that she was in danger of being overset every moment; a blast from a smith's bellows superadded had overturned her. She was proposed not to want an ounce of ballast, and yet she had in her ten tun of paving stones, and all would not do; the seamen swear they would not venture over the bar in her for 1000 pounds a piece. Even right before the wind she does nothing. So that the whole design is blown up. What measures Sir William Petty will take to redeem his credit, I know not, but I am sure a greater trouble could hardly have fallen upon him." It must all have been very interesting to Samuel Pepys, Secretary to the Admiralty, although he must have shared with others in the disappointment that had come to Petty.

Publication of Newton's "Principia"

Pepys attended, it seems, when he could, especially the meetings of Council, but, during his term of office as president, it was the vice-president who almost always presided at the ordinary meetings of the Society. At the anniversary meeting of November 30, 1685, Pepys was re-elected to Council and to the Presidency, which office he held for another year, until the Earl of Carbery was elected in his place at the anniversary meeting of November 30, 1686; Pepys, however, remained a member of Council. The most historic event during his term of office as president took place at the meeting of June 2, 1686, when it is recorded: "It was ordered, that Mr. Newton's book be printed, and that Mr. Halley undertake the business of looking after it, and printing it at his own charge; which he engaged to do." Pepys does not appear to have been present at this meeting; but his *imprimatur* as president was later given "to Mr. Newton's book", the immortal *Principia*, which was published in 1687. On June 30, "the president", in his absence, "was desired to license Mr. Newton's Book intitled, *Philosophiæ naturalis Principia mathematica*, and dedicated to the Society".

Lord Carbery chose Pepys as one of his vice-presidents on his election on November 30, 1687; Pepys was again re-elected to Council on November 30, 1687, and again chosen by Carbery as one of his vice-presidents. There is little else reported in Birch with regard to Pepys's activities in the Royal Society.

Turning to Hooke's diary, we find that there are many references to meetings with Pepys and to Pepys's kindness and friendliness towards Hooke. As for entries relating to Pepys as a Fellow of the Royal Society, there was "much discussion" at the Crown Tavern on December 28, 1676, in a company that included Pepys, Colwall, Lord Brouncker, Leak, Sir John Lowther, Sir Peter Wyche, Hoskins, Hill, Croone and Hooke, "about regulation of the Royal Society reading books, noting Experiments, order of Councell, &c.", Hooke recording also his expenditure, namely, "16d".

On June 21, 1689, after he had left the Admiralty, Pepys conversed with Hooke who recorded their talk: "Discoursd with Pepys of Dark Roome and picture box" (the *camera obscura*). Pepys had been much interested in this, as we have seen in the first part of this article, when told by Hooke some twenty-three years earlier, on February 21, 1666, that it was the best way in "the art of drawing

Pepys and his friends. This page of portraits is one of the valuable prints which are preserved in the Pepys Library at Cambridge.

pictures". It had pleased him "mightily" then and it was still of great interest; for, later in the year 1689, on October 4, he called on Hooke and once more the conversation turned to optics.

Pepys's Opinion of Hooke

It was on this occasion that Pepys offered Hooke a guinea, for some service or other that is not specified by Hooke, and Hooke refused, as he records in his diary: "Mr. Pepys calld, proferd guin, which I refused." He goes on to record his talk with Pepys: "I shewd him severall Optical Exp[erimen]ts: the Double Reflection of glass; the reason of the foci; the bringing in objects by the Telescope etc.", adding, "He invited me to dine", and so the meeting that had begun with the refusal of a guinea ended on a pleasant note. Hooke and Pepys were on good terms; they had met when Pepys was elected a Fellow in 1665, and Pepys had mentioned this meeting in his diary, as we have already noted, making the shrewd comment about Hooke that he was "the most, and promises the least, of any man in the world that ever I saw".

Again, in October of 1689, in the unhappiest year of Pepys's career, the year in which the turn of politics had forced his retirement from the Admiralty, he was present at a meeting of the Royal Society held on the 16th and occupied the Chair, as Hooke recorded: "Mr Pepys in the chair." Among other things that Hooke mentions about this meeting is "Hally [Edmond Halley, the astronomer] read his observation on Gilded Silver wire". So Samuel Pepys heard something of great interest on that day: for Halley reported what is one of the earliest attempts to estimate the size of atoms, in a paper entitled "An account of the Measure of the thickness of Gold upon Gilt-Wire, together with a demonstration of the exceeding minuteness of the Atoms or constituent Particles of Gold", which was published later in the *Philosophical Transactions* (1691, XVII, 540). It is of interest also for Halley's opening remarks that "gravity" in all bodies is "proportionable to the quantity of matter in each", as Newton had taught in the *Principia*, published only two years before Halley read his paper and published under Halley's care and, as the Royal Society was careful to direct, at his expense, and almost, so far as publication went, disregarded by its great author who, in speaking of it to Halley, referred to it as "your book". We quote from the *Philosophical Transactions*:

"What are the Constituent parts of Matter, and how there comes to be so great a diversity in the weight of Bodies to all appearance equally solid and dense, such as are Gold and Glass, (whose specifick Gravities are nearly as 7 to 1) seems a very hard question to those that shall rightly consider it: For from undoubted experiment, Gravity is in all Bodies proportionable to the quantity of Matter in each, and there is no such thing as a propension of some more, others less, towards the Earths Center; since the Impediment of the Air being removed, all Bodies descend, be they never so loose or compact in texture, with equal velocity. It follows therefore, That there is 7 times as much matter in Gold as in a peice of Glass of the same Magnitude; and consequently, that at least six parts of seven in the bulk of Glass, must be Pore or Vacuity: This some favourers of the Atomical Philosophy have endeavoured to Solve, by supposing the primary or constituent Atoms of Gold to be much larger than those of other Bodies, and consequently the Pores fewer; whereas in other Bodies, the great multitude of the intersperced Vacuities does diminish their Weights."

He continued: "Being desirous to examine this Notion of the Magnitude of Atoms of Gold, I bethought my self of the Extreme Ductility of that Metal, which is seen in the beating of it into Leaf, and above all in the drawing fine Gilt-Wire; by means whereof, I believed I might most exactly obtain the true thickness of the Coat of Gold that appears even with the Microscope, so well to represent Gold itself, that not the least point of Silver appears through it. In order to this, I inform'd my self among the Wire-Drawers, what Gold they us'd to their Silver, and they told me, That the very best double Gilt-Wire, was made out of Cylindrick Ingots 4 Inches in circumference, and 28 Inches long, which weigh 16 Pounds Troy; on these they bestow 4 Ounces of Silver one of Gold: and that two Yards of the super-fine Wire weighs a Grain. Hence at first sight it appear'd, that the length of 98 yards is in weight 49 Grains, and that a single Grain of Gold covers the said 98 Yards, and that the 10000th. part of a Grain is above $\frac{1}{4}$ of an Inch long; which yet may be actually divided into 10, and so the 100000th. part of a Grain of Gold be visible without a

Microscope. But being desirous to compute the thickness of the Skin of Gold: by means of the specifick Gravities of the Metals, *viz.* Silver $10\frac{1}{3}$, and Gold $18\frac{8}{9}$, I found the Diameter of such Wire the $\frac{1}{386}$ part of an Inch, and its Circumference the $\frac{1}{1213}$ part; but the Gold in thickness not to exceed the $\frac{1}{1345000}$ part of an Inch; whence it may be concluded, that the Cube of the hundredth part of an Inch would contain above 2433000000, (or the Cube of 1345) of such Atoms. And it may likewise be marvelled at, that Gold being stretcht to so great a degree as is here demonstrated, should yet shew itself of so even and united a Texture, as not to let the white Colour of the Silver under it appear through any the least Pores; which Argues that even in this exceeding thinness, very many of those Atoms may still lie one over the other: Which is a Consideration may merit the Thoughts of this Honourable Society, as tending to examine that renowned Atomical Doctrine, which has of late so much obtained among the Learned."

Thus, according to Halley's calculations, the number of atoms of Gold in juxtaposition over a distance of one-hundredth of an inch must be a considerable submultiple of 1345. Pepys in the Chair, and alway most eager about curious information, must have been greatly interested. How we would like to know what entry he would have made in his diary after this meeting, if he had not been forced to abandon the keeping of it on account of his eyesight.

There is a number of other entries in Hooke's diary that show Pepys to have attended meetings of the Royal Society in 1689 and 1690; but this is substantially all that we know of his activities in the Society and of his attendance at its meetings. After he had left the Admiralty in 1689, he went to live in Clapham, it is said, in retirement, but it is clear from the quotations that we have given above that up to 1690 he still appeared among his friends and acquaintances in the Royal Society.

Of those friends and acquaintances, Pepys passed various comments during the years through which he kept his diary. We have already seen what he thought of Hooke; they must have got on well together. Hooke has, probably, been much maligned for what is said to have been his uncertain temper and for his frequent claims of priority in discovery. Considering the entries that the two diarists, Pepys and Hooke, made about each other, we can scarcely avoid recalling that Aubrey described Hooke as "a person of great suavity and goodness".

Brouncker, first President of the Royal Society, was not loved by Pepys, who had been warned in 1666 that Brouncker was his enemy and who had written him down in his diary in 1667 as "a rotten-hearted, false man as any else I know, even as Sir W. Pen himself, and therefore, I must beware of him accordingly, and I hope I shall"; yet, when there was a plot in 1668 to get rid of Brouncker and Pepys from the Navy Office, Pepys wrote in his diary that Brouncker was "the best man of them all". Of Robert Boyle, as we have already mentioned in the previous article, Pepys had a high opinion. Joseph Williamson, later Sir Joseph, President of the Royal Society from 1677 to 1680 and second holder of that office, was one whom Pepys thought "a pretty knowing man and a scholler, but, it may be, thinks himself to be too much so". Williamson was Secretary to Lord Arlington, Secretary of State, and succeeded him; he was the founder of the *London Gazette*. Evelyn also had little that was good to say of Williamson.

The first edition of Newton's *Principia*, which was published under the *imprimatur* of Pepys as President of the Royal Society, is included among various books of interest from the Pepys Library.

His Interest in Microscopes

To Pepys's scientific reading there are numerous references in his diary. He was much interested in microscopes, on which he read the works of Henry Power and Hooke. On February 13, 1664, he went "to Reeves, the perspective glass maker, and there did indeed see very excellent microscopes, which did discover a louse or mite or sand most perfectly and largely"; and on July 26 of that year, he bought a microscope from Reeves. Conversing with Spong on August 7, among other matters, on the subject of "glasses", he learned that "by his microscope of his owne making he do discover that the wings of a moth is made just as the feathers of the wing of a bird, and that most plainly and certainly". And on August 13, the microscope that Pepys had bought on July 26 was delivered at his house: "There comes . . . Mr. Reeve with a microscope and scotoscope. For the first I did give him £5 10s., a great price, but a most curious bauble it is, and he says, as good, nay, the best he knows in England, and he makes the best in the world. The other he gives me, and is of value; and

a curious curiosity it is to look objects in a dark roome with." After he returned that evening, he "read a little in Dr. Power's book of discovery by the Microscope to enable me a little how to use and what to expect from my glasse". Henry Power (1623–68), F.R.S., had published his *Experimental Philosophy, in three books: containing New Experiments, Microscopical, Mercurial, Magnetical* in London in 1664.

Next day, Pepys "made an end of Dr. Power's booke of the Microscope, very fine and to my content, and then my wife and I with great pleasure, but with great difficulty before we could come to find the manner of seeing any thing by my microscope. At last did with good content, though not so much as I expect when I came to understand it better." And on the 16th Pepys spent some time "collecting observations out of Dr. Power's booke of Microscopes".

Hooke's "Micrographia"

It would be expected that Pepys would have a copy of Hooke's *Micrographia*. When he was at his bookseller's on January 2, 1665 (before he had been elected F.R.S.), "at his binder's saw Hooke's book of the Microscope, which is so pretty that I presently bespoke it". On the 20th of the month he collected his copy: "and so to my bookseller's, and there took home Hooke's book of microscopy, a most excellent piece, and of which I am very proud". Next day, after he had come home from the office, he recorded: "Before I went to bed I sat up till two o'clock in my chamber reading of Mr. Hooke's Microscopical Observations, the most ingenious book that ever I read in my life."

However, despite Power and Hooke, Pepys apparently still had some difficulty with his microscope; and on July 29, 1666, "Lord's day", as he noted, he invited Spong and Reeves to dinner: "and after dinner to our business of my microscope to be shown some of the observables of that, and then down to my office to looke in a dark room with my glasses and tube, and most excellently things appeared indeed beyond imagination. This was our worke all the afternoon trying the several glasses and several objects, among others, one of my plates, where the lines appeared so very plain that it is not possible to thinke how plain it was done."

Another scientific book that Pepys read was John Graunt's *Natural and Political Observations . . . upon the Bills of Mortality* (London, 1662), the pioneer work in vital statistics, which he bought on March 24, 1662, and found "upon first sight to be very pretty". Graunt (1620–74) was a London haberdasher. He was an original Fellow of the Royal Society, being elected on account of his work without there being any prejudice that he was engaged in trade. Sprat, the Royal Society's first historian, said of him: "in whose Election, it was so far from being a Prejudice, that he was a Shop-keeper of London; that his Majesty gave this particular Charge to his Society, that if they found any more such Tradesmen, they should be sure to admit them all, without any more ado". Graunt's book went through several editions: after his death it was re-edited and improved by Petty.

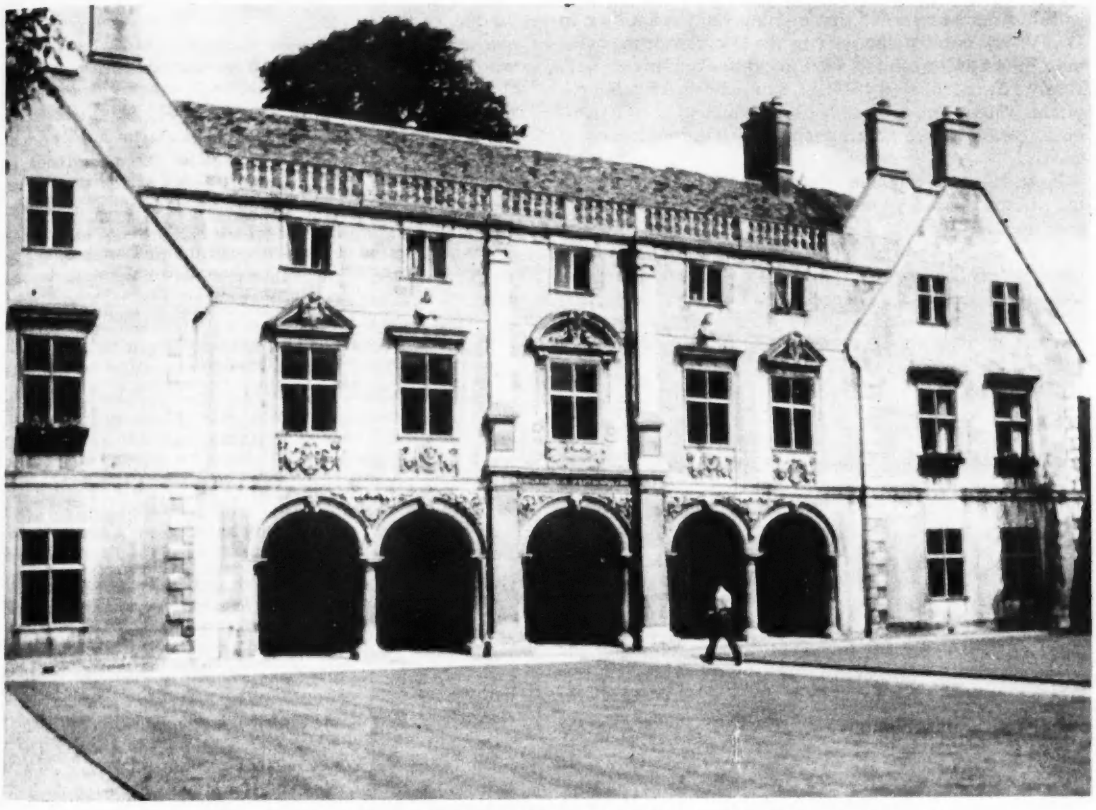
But it was Boyle's books that Pepys seems to have liked best, with one reservation. He records in his diary his reading of three of Boyle's books: *Experiments and Considerations touching Colours* (London, 1664), the work in which, among other things, Boyle applied the observation that syrup of violets turned red in acid and green in alkali to introduce into chemistry the use of indicators for acids and alkalis; *Hydrostatical Paradoxes* (Oxford, 1666); and *The Origine of Formes and Qualities* (Oxford, 1666), in which Boyle criticised in detail the scholastic doctrine of "Substantial Forms", that was still in favour among some of his contemporaries, and sought to explain the properties of bodies, not in terms of alleged innate qualities, but by reference to the effects on the senses of the textures and motions of their component particles, that is, by means of mechanical explanations.

Pepys's references to "Boyle's book of colours" begin on April 28, 1667, "Lord's day", as he notes. That morning he lay long in bed, "pain in my back being still great, though not so great as it was". He added: "However, up and to church, where a lazy sermon." But, after dinner, he went on the river: "After dinner, by water—the day being mighty pleasant, and the tide serving finely, I up (reading in Boyle's book of colours), as high as Barne Elmes." Then he heard another sermon at Putney Church and afterwards, the tide being with him again, went down river to Deptford to the dockyard. That night he recorded that he was "mightily pleased with my reading of Boyle's book of colours to-day, only troubled that some part of it, indeed the greatest part, I am not able to understand for want of study". Again, on May 26, also "Lord's day", he turned to this book once more and again on the river, coming down from "Barne Elmes" and found in it "many fine things worthy observation"; and on June 2, again "Lord's day", he returned to it: "Being weary and almost blind with writing and reading so much to-day, I took boat at the Old Swan, and then up the river all alone as high as Putney almost, and then back again, all the way reading, and finishing Mr. Boyle's book of Colours, which is so chymical, that I can understand but little of it, but understand enough to see that he is a most excellent man."

Hydrostatics and a Dutch Attack

The next book by Boyle that Pepys turned to was the *Hydrostatical Paradoxes*, only two days later and in curious circumstances that might well have delighted the author himself, had he known anything of the matter. Under the date of June 4, 1667, Pepys recorded: "To the office all the afternoon, where I dispatched much business to my great content, and then home in the evening, and there to sing and pipe with my wife, and that being done, she fell all of a sudden to discourse about her clothes and my humours in not suffering her to wear them as she pleases, and grew to high words between us, but I fell to read a book (Boyle's Hydrostatiques) aloud in my chamber and let her talk, till she was tired and vexed that I would not hear her, and so become friends."

On June 10, when the Dutch Fleet was at the Nore, and Pepys was urgently concerned with the preparation of fireships, he went down to Deptford on this duty and, although he was well supplied with money, he could not get the work done quickly enough, partly because "people that have



The Pepys Library, Magdalene College, Cambridge, was built in the middle of the seventeenth century, but the date on the front is 1724, the year when Pepys's books came to the college.

been used to be deceived by us as to money, won't believe us", on which he commented "that it is an admirable thing to consider how much the King suffers, and how necessary it is in a State to keep the King's service always in a good posture and credit". From Deptford, he went on to Greenwich and then to Gravesend, where he could plainly hear the gunfire of the Dutch, but on his return journey he recorded: "So I homeward, as long as it was light reading Mr. Boyle's book of Hydrostatics, which is a most excellent book as ever I read, and I will take much pains to understand him through if I can, the doctrine being very useful." Darkness came on and Pepys "took a nap" and got home at one o'clock with the book that had proved a happy distraction alike in domestic strife and in the more urgent business of dealing with the King's enemies.

Again, on July 24, after a heavy day's work on the preparation of "the accounts of the Navy presented to the Parliament at their last session", he went down to Gravesend, "all the way with extraordinary content reading of Boyle's Hydrostatickes, which the more I read and understand, the more I admire, as a most excellent piece of philosophy"; and as he drew near to Gravesend, he could hear "the Dutch fleete and our's a-firing their guns most distinctly and loud". On August 25, "Lord's day", he went up the river to Putney and walked to "Barne-Elmes", "reading of Boyles Hydrostatickes, which are of infinite delight".

Pepys already possessed, it seems, a copy of Boyle's *Origine of Formes and Qualities*: for, on April 1, 1668, he bought a copy of the new edition (Oxford, 1667) and sent his old one to his brother. On January 29, 1669, in the evening, as he records: "we home, and there hired my wife to make an end of Boyle's Book of Formes, to-night and to-morrow". It does not appear, from what followed, that he had read the book, although he owned a copy of the earlier edition: it seems that he had no liking for it and that he finished the reading of it by proxy. For, of the afternoon of the next day, William Batelier being his guest, Pepys recorded: "I spent all the afternoon with my wife and W. Batelier talking, and then making them read, and particularly made an end of Mr. Boyle's Book of Formes, which I am glad to have over."

(The first two illustrations are reproduced, by kind permission of the Master and Fellows of Magdalene College, from the booklet about the Pepys Library which has just been published and is obtainable from: The Office, Magdalene College, Cambridge, price 2*s.* 9*d.*, post free.)

(*To be concluded*)

In Australia, rabbits infesting grazing land eat the rations of 40 million sheep. These pictures give a vivid impression of the scale of the rabbit problem. Merely to keep the rabbit from invading good land is an expensive undertaking; rabbit-proof fencing today costs about £800 a mile. The first trials with myxomatosis control open up the prospect that Australia may be able to clear much of the land that is so completely occupied by rabbits as to be useless for farming.

Australia's War Against the Rabbit

It all began in 1859. And so innocently. The clipper ship *Lightning*, dropping anchor in Hobson's Bay, Australia, discharged two dozen rabbits, consigned to Thomas Austin of Barwon Park. The inoffensive little animals were imported to provide sport for the settlers. But soon Austin had far more rabbits to hunt than he had ever anticipated. Within six years he slaughtered 20,000 rabbits and assessed that at least 10,000 or more still roamed his estate.

Others settlers encountered similar troubles. And what had originally been a protected animal was now vehemently outlawed. No one had foreseen that the rabbit—cheerfully denuding the land of its grass—would threaten to overrun the continent within a decade or so. The State put a price on his head: a bounty of a shilling. Landowners, starkly alive to the danger, mobilised all their resources to exterminate him. Australia's war on its biggest scourge had begun.

So serious is this rabbit pest today, that each year Australian sheep farmers suffer a loss in production of between £30 and £40 million. In turn, the world is deprived of valuable merino wool. It is estimated that four and a half rabbits eat as much grass as one sheep. And because they multiply at an astounding rate, there can be no easing-up of the war. Four weeks after mating, a pair of rabbits has an average litter of six offspring. As the does in the litter can themselves reproduce fifteen weeks later—and invariably do—it is easy to gauge the extent of Australia's problem.

The campaign has undergone phases of varying success. As enemies, hawks, weasels and snakes have proved ineffective. Thousands of miles of wire fences have been erected at great cost, but these are difficult to maintain; at least 300,000 miles of new fencings are vitally needed. So far, one of the most successful techniques has been strychnine poisoning; another depends on the use of bulldozers. The bulldozers are deployed against the rabbit warrens, crushing and suffocating many of the inmates. The ones that survive are destroyed by dogs or by men carrying shotguns. As many as 13,000 rabbits have been liquidated in a single field of a thousand acres by this method.

Now wool-growers have a new weapon. It is myxomatosis, a virus disease specific to rabbits. So promising have experiments been that Mr. R. G. Casey, Minister-in-Charge of the Commonwealth Scientific and Industrial Research Organisation, which is Australia's equivalent of Britain's D.S.I.R., claims: "Although it will not eliminate the rabbit throughout Australia, myxomatosis will be an appreciable if not a substantial factor in its control."

Myxomatosis, first described by Dr. G. Sanarelli in Montevideo in 1898, had been widespread in South American countries before that date. Its use as a means of rabbit control was first suggested by Dr. H. de B. Aragao of the Argentine Instituto Oswaldo Cruz in 1928.

During the 'thirties, various outbreaks in California were studied by Dr. Shillinger of the Disease Investigation Division of Wild Life Research in Washington. In 1936, Shillinger definitely established that mosquitoes could spread the virus among rabbits. This was first revealed when Shillinger corresponded with Sir Charles Martin at the Molteno Institute of Animal Pathology, Cambridge. The latter, at the request of Viscount Bruce, then High Commissioner for Australia in London, was studying an infection of myxomatosis virus strains obtained from Dr. Aragao and the Rockefeller Institute for Medical Research.

During 1936–8 Sir Charles took part in three large-scale field experiments in Europe: on Skokolm Island in the Bristol Channel, Vejro Island (Denmark) and Dufeke Estate (Sweden). The outcome of this research was notable in that transmission of myxomatosis at Skokolm and Vejro was poor, but at Dufeke there was almost complete rabbit extermination. Sir Charles suspected that this was due to mosquitoes or other blood-sucking insects. Because of Sir Charles's investigations, the work was transferred to the Australian C.S.I.R.O.'s Division of Animal Health, where it was continued from 1936 onwards mainly under the direction of Dr. L. B. Bull and M. W. Mules. These two men demonstrated in 1938 that the virus could be disseminated effectively by mosquitoes.

Last summer Australian scientists spread the greatest man-made epidemic in history over an area about half the size of Europe. The greatest concentration of myxomatosis was in the Murray River system in South-eastern Australia. Observations revealed that the disease tended to be more virulent along the river flats and frontage country. Indeed, there was a clear relation between the activity of the disease and the proximity of weedy lagoons, the breeding-place of the night-biting mosquito, *Culex annulirostris*, and its day-biting counterpart, *Aedes*. Other vectors, however, were also noted: blackflies (*Simulium*) and stickfast fleas.

In his recent statement Mr. Casey declared that myxomatosis "has come to stay". This assertion is due to recent, surprising developments which could not have been foretold from last season's observations. Another artificial epidemic is now under way and promises to destroy to a degree exceeding that achieved in 1950–1.

The disease is proving lethal in many districts where only sporadic cases were seen last summer. In some substantial areas, kills amounting to 90% or better have been secured.

An impetus to the disease is being given by inoculating rabbits artificially. To achieve this, scientists take a swab from the eye of a diseased rabbit and run it into the eye of a healthy one. Alternatively, the infective material can be smeared on a scarified patch of skin on the animal's face. A diseased victim with well-developed lesions in the eyelids and conjunctivae can supply enough material to inoculate a dozen or more rabbits.

While at this stage of the disease, the organs are frozen hard in a refrigerator, then ground in a cooled, domestic-type mincing machine. After weighing the resultant fine paste, nine parts of 50% glycerine in phosphate buffer solution is added to give a 10% suspension of the tissue. Ice crystals in the frozen tissue are essential if it is to be ground adequately.

An ordinary spring-type steel rabbit trap is used to infect rabbits in selected warrens. The eye of the spring is cut so that only one jaw operates, and a small, mild-steel block is welded to the under-side of the release catch. Next, two striking pins at an angle of 45° are welded to the active jaw, and two inoculating pins are fitted on the striking pins with small pieces of rubber tubing to give small chambers to contain the virus material. To infect mosquitoes in the field and thus set up an epidemic, inoculated rabbits are exposed in netting cages.

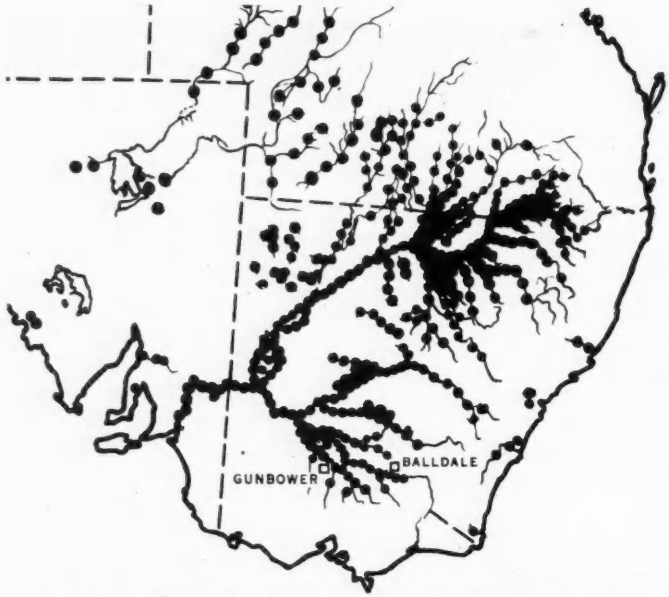
So that the mosquitoes can feed on the rabbit undisturbed, an area of fur on each side of the animal is clipped to the skin. Once inoculated, rabbits are capable of infecting mosquitoes feeding on them in about seven days' time. Under laboratory conditions, species of the genus *Aedes*, after a single infective feed, can infect rabbits for about a fortnight. The rabbits usually develop myxomatosis on the seventh day after infection; the incubation period may be a little longer—up to ten days. Myxomatosis first reveals itself as oedema of the eyelids with congestion of the blood vessels of the conjunctivae. A small amount of purulent material collects at the inner canthus of the eye. Clinical signs increase rapidly; the rabbit grows more lethargic, the eyes become half closed and the head more swollen.

Although in the laboratory the disease proves virtually 100 per cent lethal, the occurrence of recovered animals in the field has been noted in some areas. It is believed to be the result of a less virulent strain of virus—a development which experts anticipated. Perhaps a virus of lower virulence will set up a sub-lethal infection throughout the rabbit population and result in a high proportion acquiring immunity to the more deadly form. Sir Macfarlane Burnet, Director of the Hall Institute, Melbourne, and Professor F. J. Fenner of the National University are studying this problem.

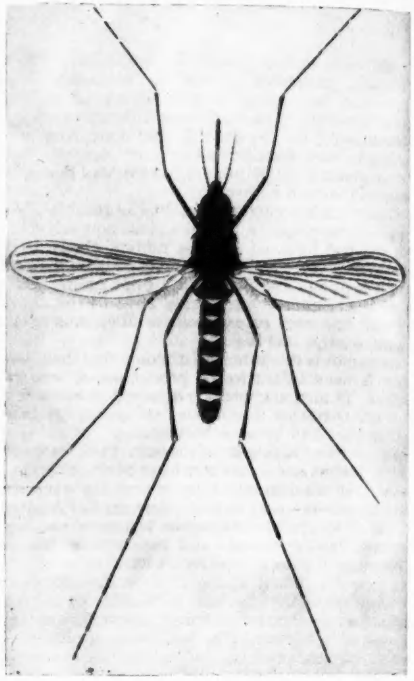
As in the case of many innovations, certain wool-growers treat the disease with some suspicion. They have blamed myxomatosis for any sickness or deaths among domestic or wild animals in epidemic areas. In actual fact the disease merely affects rabbits. To prove that myxomatosis has no effect on human beings Sir Macfarlane Burnet, Professor Fenner and Dr. Ian Clunies Ross, chairman of the C.S.I.R.O., submitted themselves to doses of myxomatosis one hundred times bigger than a mosquito could inject into a human being after the insect had bitten an infected rabbit.

Though the disease still retains some of its secrets, as Mr. Douglas T. Boyd, chairman of the Australian Wool Board, remarks: "It now appears that the wool-growers have been given an effective weapon enabling them to subdue the rabbit pest to a point where there is little danger."

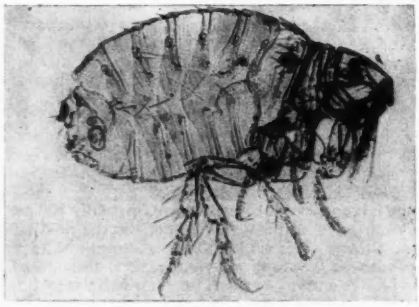
DOUGLAS LIVERSIDGE.



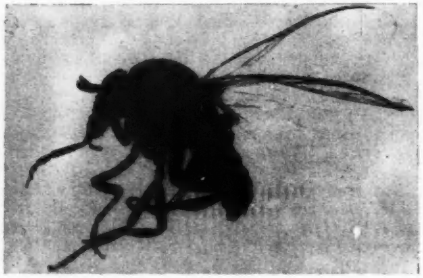
Australian interest in the idea of using myxomatosis to exterminate rabbits was aroused in the early 1930s. Seven years' work by the Animal Health Division of the Commonwealth Scientific and Industrial Research Organisation established that the disease is lethal to rabbits but does not affect domestic animals. Then the experimenters benefited by a lucky accident; a small-scale trial in which rabbits were injected with the virus unexpectedly developed into an epidemic outbreak of the disease. It spread all along the branches of the River Murray system (as shown in map), and it was realised that mosquitoes and similar insects were man's allies in the war against the rabbit.



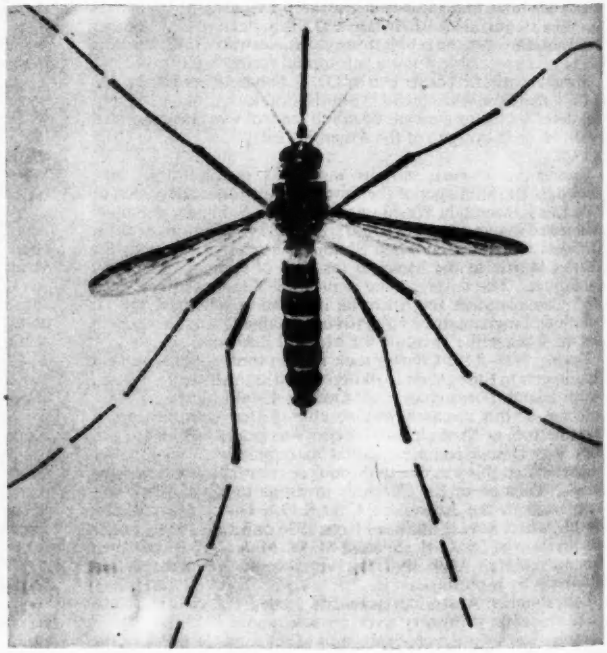
Four insects which transmit myxomatosis are shown on this page. The most effective of them is *Culex annulirostris*.



Echidnophaga myrmecobii, the stickfast flea.



A blackfly (*Simulium sp.*).



Aedes aegypti.

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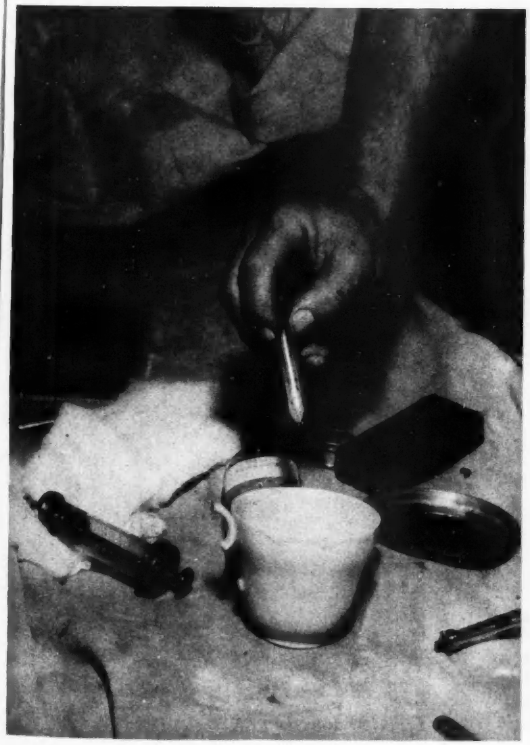
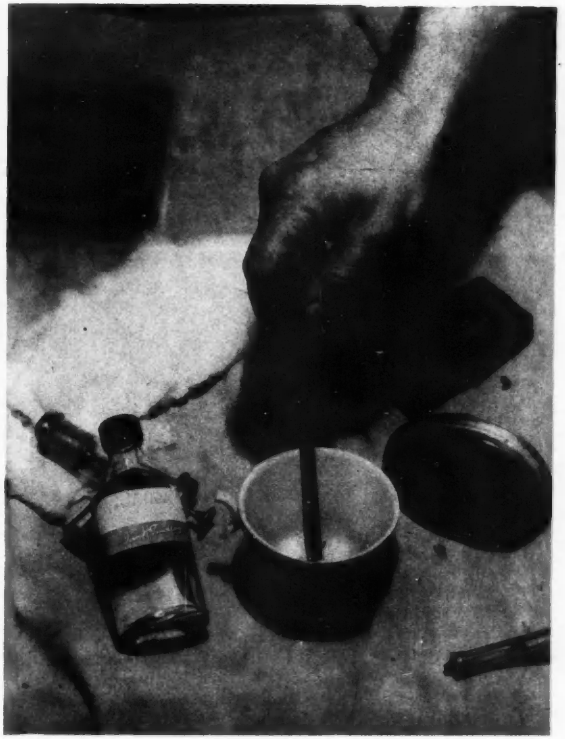
The dried virus preparation is being distributed to centres all over Australia for use in the present intensive campaign against the rabbit. This is made by drying the infected organs and grinding them into a powder, which is distributed in phials. One small thimbleful of the pinkish dust is death for hundreds of rabbits.

In the field the virus preparation is mixed with water, and injected into rabbits by means of hypodermic syringes. The fact that one single research station sends out each week enough dried virus to kill 25,000 rabbits indicates the scale on which this war of extermination is being waged.





To create a focus of myxomatosis artificially in a particular locality, the first step is to round up as many rabbits as possible.

The rabbits have been collected into a corner of the net, and are ready to be moved into pens.

Originally it was intended to distribute dried virus to farmers and let them do the inoculating. But this plan was modified when it was realised that the inoculation procedure was too tricky for the farmer to take on. The virus needs careful handling; for instance, accidental exposure to sunlight can reduce its potency considerably, and the weakened doses might fail to kill infected rabbits, so discrediting the technique among farmers; furthermore, there would be the risk of building up resistance to disease among local rabbit populations.

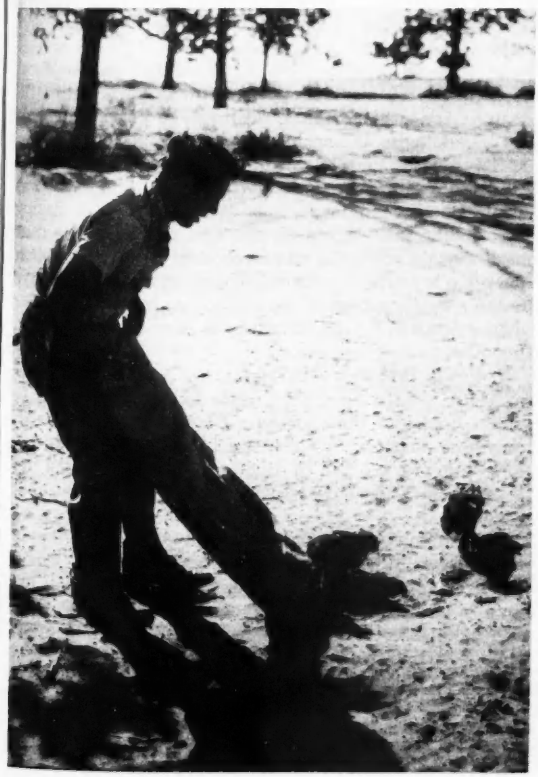
A rabbit is being injected.

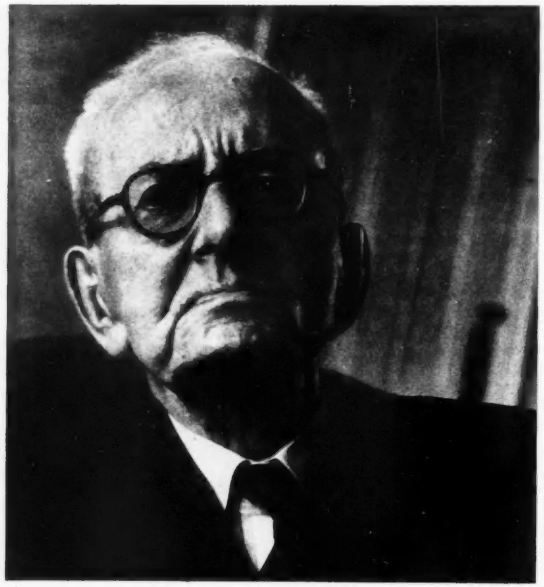
Below: Artificially infected rabbits are taken from the pens and are here seen being released on a sheep farm.

Top right: In the first few days after injection the rabbits are quite lively, and distribute themselves among their uninfected fellows; this natural mix-up leads to the situation where insects can proceed to spread the disease rapidly as soon as the infected animals reach the infectious stage.

Centre right: Within six days of infection rabbits begin to show serious symptoms; the general effect has been compared to that of a very violent cold accompanied by kidney trouble. The eyes become clogged with a discharge, which is itself extremely infectious.

Bottom right: Myxomatosis kills in a matter of twelve to fourteen days.





Sir Charles Sherrington (1857-1952)

It was a very great privilege, as well as a most interesting experience, to meet and photograph Sherrington, and my delight knew no bounds when he chose my portrait as the frontispiece to the second edition of his masterpiece, *Man On His Nature*, which was published on his 94th birthday, in November 1951.*

Sir Charles Sherrington promised me "only half a minute" to get the picture I had asked for. I was shown into his study and sat down on the coal-box on the opposite side of the fire from the great scientist and hastily focused my camera. I could see his alert dark eyes fixed on me and it seemed that he was impatiently waiting for me to take him and be gone again. I took three exposures rapidly, thanked him, and was at the door when he stopped me. "Hey, wait a minute," he said, holding out his hand. "I'm doing this as my Sunday good deed."

I saw then that his eyes were twinkling with good humour and he was smiling broadly.

Sir Charles Sherrington was an astonishing man. The world of science knew him and honoured him as possibly the greatest physiologist since William Harvey.

Over the course of his long life as a scientist, Sir Charles contributed more to the fund of knowledge about the brain and the central nervous system of the body than possibly any other man who ever lived. Universities all over the world recognised his genius, and honorary degrees were conferred upon him by no fewer than twenty-two different universities. Famous scientists of many nationalities count it an honour to have been his pupils.

* *This is the photograph reproduced on this page.*

Sherrington was wonderfully human and unpretentious at close quarters. There was little about him to suggest that he had solved some of the innermost puzzles of the mind. Beyond his scientific interests Sherrington delighted in poetry; he himself had published several books of poems, some of them strangely inconsequential. Keats and Tennyson were his favourites.

His wide range of outside interests was very diverse, including, for instance, the Roman wall; the history of mechanical inventions; Gothic architecture; Dutch painting; old books; Canada. He entered into his studies on these subjects with all the original freshness of approach that he brought to bear on the abstruse physiological researches which occupied his working days.

Sherrington was born in 1857 and went to school in Ipswich. He later studied at Caius College, Cambridge, and after graduating became Brown Professor of Pathology at London University and Lecturer in Physiology at St. Thomas's Hospital. During that time, in 1894, with the assistance of Armand Ruffer, he became the first man ever to make diphtheria antitoxin in Britain. A few months later he was the first man in Britain to use this antitoxin when he injected it into his sister's seven-year-old son, who was desperately ill with diphtheria.

Gradually he turned his attention to the study of reflex actions—those actions which enable a person to walk without having to think about it, or to move his arms or his head or his eyes without conscious effort. His 'magnum opus', *The Integration of the Nervous System*, was first published in 1906, and became the basis of all modern knowledge of the complex workings of the brain and nerves.

In 1940 he published his views on the philosophical implications of his findings of a lifetime's scientific research. He surveyed the world from the point of view of the physiologist, taking into account man's capacity for moral intuition and judgment.

He once said: "Aristotle, two thousand years ago, was asking how the mind is attached to the body; we are asking that question still." But his theories, which have as their basis that the mind has an independent existence and that the brain is merely the organ through which it works, have become widely accepted. He lived to see many of his other theories proved by scientists who have worked on his first hypotheses.

It was in 1924 that Sherrington was awarded the Order of Merit. At the time of his death he was thus by far the oldest holder of that honour. The O.M. was, however, only one token of great respect in an extraordinarily long and varied list of honours, which included the Presidency of the Royal Society and the Nobel Prize for Medicine.

Sherrington was so modest, shy and retiring that some of his most faithful students have described it as almost embarrassing until the friendliness and kindliness of this man of genius have become apparent.

Speaking for myself, the sincerity and warmth of his simple "Good-bye" as we parted will remain with me always, as will the conviction that the very greatest men of all are almost invariably the most modest and unassuming, and the most eminently human of human beings.

Allan Chappelow.

LETTER TO THE EDITOR

The Capital Costs of Fuel Saving

THE May number of DISCOVERY contains an editorial comment on my article "Energy in the Future" to which I must reply briefly. While the editorial is not in disagreement with my scientific and technical arguments it questions one particular point on economic grounds, a point which centres on the question of how much capital has to be invested in order to save one ton of coal per annum by improving domestic heating. In actual fact I have given a more detailed discussion of these matters in a lecture at the Royal Institution some time ago, and in a number of articles in my book *The Neglect of Science*. In the present article written for Unesco (which overlaps to a certain extent with the lecture mentioned above) I devoted hardly any space to this part of the problem, but concentrated on the prospects for the more distant future. The point under discussion came into the picture in quite a secondary way when I made a rough comparison of the capital investment needed to save coal in various ways; for this an approximate figure was quite sufficient.

I first developed this last argument in the Royal Institution lecture (see DISCOVERY 1949, p. 88): there is no justification for investing large sums of money in a power project if the same amount of coal can be saved at much lower cost by improving our domestic heating appliances. I applied this specifically to the tidal power projects—a point in which I was supported later on by Dr. Bronowski. I agree with the Editor that a very thorough survey should be made as to how much could be saved in the domestic field and I hope that the Ridley Committee will have something to say about this matter. At the moment it will suffice to refer to various discussions, for instance in *Picture Post*, which shows that my data cannot be very wrong—assuming of course that the modern appliances are mass-produced. It may be that the figure for a capital investment of £2 10s. for each ton of coal saved per annum is somewhat on the low side, but it is difficult to give exact figures in these times of changing prices—this by the way would also alter the figures for the cost of the Severn Barrage Scheme. But even if we do not change the figure for the Severn Barrage, namely a capital investment of £100 for each ton of coal saved per annum, it is quite obvious that it is at least higher by a factor of 10 than the capital investment required to save the same amount in domestic heating. I therefore maintain that there can be no justification for embarking on a project like the Severn Barrage before the much greater possibilities of saving coal in other fields are fully exploited.

Again, I cannot go into details over the economic possibilities of district heating, but the Pimlico Scheme shows that this way of saving is definitely a practical proposition; this is also borne out by the fact that district heating from pass-out turbines is gaining ground steadily in the United States. I am therefore unable to understand the relevance of the last of the Editor's remarks.

May I take this opportunity of adding the last lines of my article which in some way have been lost in the printing, with the result that the article ended rather abruptly.* After having mentioned that some people advocate the stopping of all research because, in their opinion, science is responsible for the present troubles, I discussed the futility of this argument and referred to the fact that we would then also have to stop biological and medical research because of its military applications. I finally ended up with the following sentences:

"Indeed, those who hold this view should logically direct their attention to the possibility of banning the printing press, as it is misused so frequently by an irresponsible Press all over the world. What matters is that one uses the inventions in the right way, and in this respect scientists can do no more than other persons, particularly as they do not seem to possess more than the average political sagacity."

F. E. SIMON

** This passage had to be cut simply because there was no space to print it. We still think Prof. Simon's figure of £2 10s. is quite unreal; £25 would probably be nearer the mark. With regard to the Pimlico Scheme, a complete analysis of its economics has yet to be published.*—Editor.

Far and Near

Tapping Australia's Uranium

BOTH Britain and the U.S.A. are taking an active interest in the development of Australian uranium deposits. On April 2 this year the Australian Premier, Mr. Menzies, announced an agreement whereby Australian uranium can be made available to the U.S. Atomic Energy Commission.

The leader of the delegation to Australia from the United States Atomic Energy Commission, Mr. Jesse Johnson, has named 1954 as the year in which Australia should begin production of uranium ore on an important and economical scale. Mr. Johnson made this statement on April 3 before leaving Sydney for London, where he has conferred with British officials about the Australian project. He confirmed that production of uranium ore in Australia should be achieved without large contributions of capital from either the U.S.A. or Britain.

Mr. Johnson said that the fields at Radium Hill, in South Australia, and at Rum Jungle, in the Northern Territory, made Australia a potentially important producer of uranium, but only time and exploration would determine truly the wealth of these fields. He added that Australia already possessed adequate resources and knowledge to undertake development of the Radium Hill field, but American and British help would be available if needed.

The preparation of uranium metal from the crude ore is an intricate process. The Australian Premier has stated that as much as practicable of the refining process would be carried out in Australia. *The Times* (30/4/1952) reports Mr. Menzies as saying, in connexion with the suggestion made in the Australian Press, that no Australian uranium should be exported until she had established adequate stocks for domestic use, that after providing sufficient for her own needs "Australia could still supply the United Kingdom and the United States for research and defence purposes". He added that neither the Commonwealth nor the South Australian Government had lost sight of the possibilities of uranium for domestic use, but this was clearly some way off. Meanwhile the Commonwealth Government did not intend to refuse supplies needed for military purposes. It was vital for the democratic countries to maintain their lead in the atomic field.

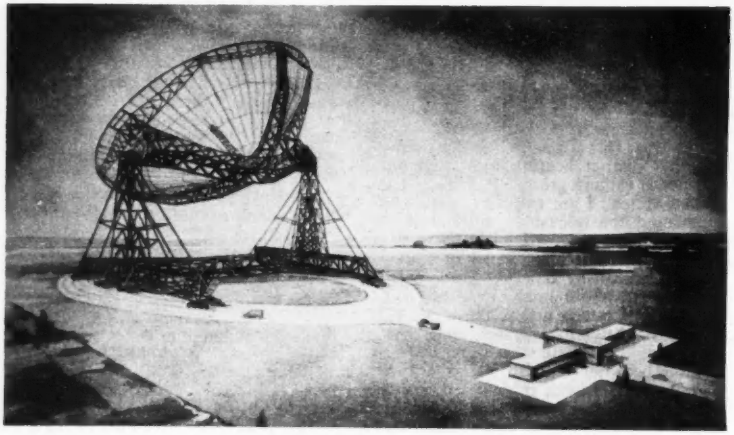
The British Association Meeting

THIS year the British Association meets in Belfast from September 3 to September 10. Just one hundred years after it held its first Belfast meeting. In all, eight meetings have been held in Ireland—three in Belfast, four in Dublin, and one in Cork.

An interesting innovation will be the series of five lectures for young people which will be delivered in the Whitla Hall, Queen's University, on the afternoons of September 4, 5, 8 and 9 and on the morning of September 6. These lectures will be given by:

Mr. R. J. Bartlett, on "Seeing is Believing";
Prof. G. H. Bell, on "Noises Old and New";
Mr. C. R. Ribbands, on "The Honey Bee";
Dr. W. E. Swinton, on "Animals of the Past";
Mr. F. Kingdon-Ward on "Travel and Adventure on the Roof of the World".

Special tickets of admission for these junior lectures will be issued to student members of the Association who make application to Major E. R. H. May, Room 43, City Hall, Belfast, *not later than June 4*, after which date all remaining tickets will be distributed among senior



An artist's impression of how Manchester University's giant telescope will look when it is complete. Construction is to begin this year. The instrument is designed so that it can be directed at will to scan any part of the sky and to follow the course of any particular star. Diameter of the paraboloid is 250 ft. The telescope will weigh 1270 tons. The cost of £336,000 is being shared by the D.S.I.R. and the Nuffield Foundation.

schoolchildren in Northern Ireland under an arrangement of which details will be notified to schools by the N.I. Ministry of Education.

Copies of the preliminary programme for the British Association meeting can be obtained from: D. N. Lowe, British Association, Burlington House, Piccadilly, London, W.1.

A Chemical that Fattens Pigs

THE remarkable results obtained by adding aureomycin to the diet of pigs and chickens were described in the December 1951 issue of DISCOVERY ("Antibiotic + Vitamin = Boom Food", by Chapman Pincher, pp. 376–9). This article referred to pig-feeding experiments which had been started in Britain—at the National Institute for Research in Dairying, at the Rowett Research Institute, Aberdeen, and the British Oil and Cake Mills at Stoke Mandeville. Tests are now under way in Britain with penicillin; there is evidence that the spent mould from the factories making this antibiotic could be used to 'fortify' conventional feeding-stuffs in a similar way as aureomycin is being used.

The reasons why aureomycin should exert such a remarkable effect on the growth of animals to which it is fed are obscure, as A. L. Bacharach stressed in his "Science Survey" broadcast of April 18, which was appropriately entitled "A Chicken-house Mystery".

* * *

A new development in this field is reported from the U.S.A. where Armour & Co. of Chicago has disclosed the results of a test in which the effect of a fatty acid derivative was compared with that given by aureomycin. This test seems to indicate that the chemical is at least equal to the drug in putting weight on hogs.

The test was made by a team of researchers at Michigan State College agricultural experiment station, East Lansing, Michigan, using a chemical supplied by Armour. This chemical is known as Ethomid C/15, which is one of several hundred chemicals made from fats and oils in the new Armour plant at McCook, Illinois, near Chicago, which was built three years ago after a 20-year research programme to find better uses for these substances. (The word 'ethomid' is the trade name for a series of non-ionic surface-active agents manufactured from fatty acids and used as detergents and emulsifiers. To make an ethomid, the fat molecules are first split with steam to separate the component fatty acids from the glycerine with which they are joined in nature. The acids are then purified by fractional distillation and reacted with ammonia to produce amides, which are in turn reacted with ethylene oxide to make ethomids. 'Stergene' and 'Lissapol' detergents which are commercially produced in Britain are related to these substances.)

In the Michigan State College test, four groups of young Yorkshire hogs were used. To one was fed a standard ration of corn, meat and bone scraps, soya meal, minerals and vitamins. To the second they fed the standard ration plus small amounts of ethomid. The third got the ration plus aureomycin; the fourth, the ration plus both ethomid and aureomycin.

The first group gained 1·1 lb. a day per hog. The ethomid and the aureomycin groups both gained 1·29 lb. a day, while the combined fourth group averaged somewhere in between. The researchers found that, while the gain from aureomycin was manifested immediately and then levelled off, the gain from the ethomid was slow in starting, but then rose rapidly and, as the experiment proceeds, continues to climb.

From the standpoint of the farmer, the interest of the demonstration lies in the fact that the chemical can be fed at much lower cost than the antibiotic.

The fact that antibiotics in the diet will increase the weight-gain of swine was first published a year or so ago and such drugs as aureomycin are now being fed to the animals by many U.S. farmers. It was believed that the antibiotics worked by inhibiting 'unfavourable' bacteria in the gut and encouraging the growth of 'favourable' organisms. However, a physical chemist then pointed out that all the antibiotics used were surface-active or 'wetting' agents and were therefore likely to have a side-effect comparable to that shown by detergents, which might lead to more effective absorption of food in the animal's gut. That opened the question whether the reduction of surface tension, rather than germ-killing, was the important property and a series of experiments designed to answer it has begun.

Armour chemists regard the Michigan State College test only as a beginning which opens up a new idea in nutrition. The bactericidal theory seems questionable now, but a number of other feeding studies with surface-active agents already in progress has so far produced no definite explanation of how the chemical works. It is suspected that rather than killing germs it makes the food more readily assimilable by reducing its surface tension.

Sir Edward Appleton, Film Star

THE BBC Television Service began a year ago to make a series of films about famous people. The first film, showing the aims and methods of the sculptor Henry Moore, was awarded a first prize at the 1951 International Film Festival at Venice. The second film in the series is now in active preparation, and will bring to the screen the distinguished scientist Sir Edward Appleton.

The film will deal with the nature, methods and importance of scientific research, and Sir Edward's own contribution to radio-physics will be explained. Later developments which have evolved in the same field will be shown, and it is hoped to illustrate the latest contribution of radio to astronomy.

The film is written and directed by John Read, and the cameraman is Alan Lawson.

Two Publications on Pest Control

THE papers delivered before the international crop production conference held at the Fernhurst Research Station last summer have now been published in book form. Scientists who wish to secure a free copy of this document should apply to Plant Protection Ltd., 61 Curzon Street, London, S.W.1.

* * *

Pest Control Ltd., of Harston, Cambridge, have produced a new edition of their *Farmers' Handbook on Pest Control*. This is a lavishly produced pocket-book (Crown octavo), spirex-bound with limp covers, compiled by Dr. W. E. Ripper, A. L. Abel, R. M. Greenslade, S. G. Jary and R. W. Shorrock. Farmers and agricultural scientists are invited to write to Pest Control for a copy.

Underwater Television

THE use of television under water has been the subject of much research and development during recent months. Twelve months ago, Marconi's Wireless Telegraph Company Ltd. was brought in by the Admiralty to help in the search for the lost submarine *Affray*, and a new field of television application was thus opened. Since then the Marconi Company has been intensively investigating the problems of underwater television, and during recent months, in collaboration with Siebe, Gorman & Co. Ltd. (the well-known manufacturers of respirators and diving equipment), this firm has been developing pressure casings suitable for containing TV cameras under water, and also lighting gantries which can meet the requirements of underwater television.

The sensitivity of the TV camera which has been perfected as a result of these efforts was shown at a demonstration held at the Tolworth works of Siebe, Gorman & Co. in April. This demonstration also established the potentialities of the method in any type of underwater work where it would be dangerous for a diver to descend, and for use at depths far greater than a diver's limit. In major salvage operations one of the greatest drawbacks has so far been the 'blindness' of the surface officers directing operations. With the new TV equipment they will now be able to follow the operations, direct movement and technique, and brief relief divers *visually* before they go down to take over. This will lessen the reliance of a diver's verbal report and will be of inestimable help to those in charge on the surface and to the divers themselves.

A TV camera can work for far longer periods under water than a diver could; the Image Orthicon pick-up tubes in the TV cameras are far more sensitive and accurate than the human eye, a point of particular importance under water where visibility is necessarily bad, while, in matters of interpretation, it allows scientists and experts to *see* what is below, thus eliminating the discrepancies which must creep into a diver's report—the diver often having no specialised knowledge of the flora, fauna, machinery and geological vista he is sent down to inspect. At great depths pressure has an adverse effect on a diver's judgment and discrepancies of size and distance become all too frequent. Another very important advantage is that the television picture received on board a ship from a submerged camera can be filmed and a permanent record obtained.

So far in these experiments standard TV cameras similar to those used extensively by the British Broadcasting Corporation for outside television broadcasts have been used. The new camera is fitted with extra facilities designed to allow flexible control from a remote position in lieu of a cameraman.

Apart from the experimental side of underwater television the Marconi equipment has already proved highly successful in the finding of the *Affray* at a depth of 280 feet. Knowledge gained on that occasion is now being put to use and a pressure casing for containing the camera is being designed and produced. These casings will have viewing windows through which the lens of the cameras will 'shoot' the underwater scenes. A new type of gland has been devised for the camera cable. The cable is of special construction and is capable of being operated at depths of over 1000 feet.

The Marconi cameras have been used at varying depths, and it has been found that in certain conditions good pictures are obtained as deep as 80 feet without the aid of artificial light. Tests made under practical conditions at sea show that artificial illumination of the object is of doubtful value when the water is clear, but many more results will have to be compiled and obtained before firm conclusions can be justified. Another interesting point shown by these sea tests is that tungsten lighting appears to give better results than either sodium or mercury vapour light.

Under test conditions some applications have already been thoroughly tried out—study of wrecks, finding of objects and the investigation of the sea bed—and others which present themselves are the study of fish in their natural surroundings, the investigation of trawl nets under operational conditions, identification and control of oyster and scallop beds, inspection of dock gates and ships below the water line without employing divers or using dry docks, and the possibility of undertaking really deep-sea research to depths exceeding 1000 feet.

Night Sky in June

The Moon.—Full moon occurs on June 8d 05h 07m, U.T. and new moon on June 22d 08h 45m. The following conjunctions with the moon take place:

June					
3d 09h	Saturn in conjunction with the moon		Saturn	7°	N.
5d 01h	Mars	,,	Mars	4°	N.
18d 14h	Jupiter	,,	Jupiter	6°	S.
23d 20h	Mercury	,,	Mercury	9°	S.
30d 18h	Saturn	,,	Saturn	7°	N.

The Planets.—Mercury rises about a quarter of an hour before the sun on June 1 but cannot be seen, and is in superior conjunction on June 9. After this it becomes an evening star, setting at 21h and 21h 40m on June 15 and 30 respectively—in the latter case about 1h 20m after sunset—and can be seen in the western sky. Venus is in superior conjunction on June 24 and is too close to the sun during the month for observation. Mars sets in the early morning hours—at 2h 10m, 1h 10m and 0h 15m on June 1, 15 and 30 respectively. Throughout the month the planet is a little south of $\varkappa$ Virginis and its stellar magnitude decreases from $-1{\cdot}1$ to $-0{\cdot}5$ between June 1 and 30. Jupiter is a morning star, rising at 2h 40m, 1h 50m and 0h 55m on June 1, 15 and 30 respectively, stellar magnitude $-1{\cdot}6$. Saturn sets in the early morning hours—at 1h 50m, 0h 55m and 23h 55m at the beginning, middle and end of June respectively—and is very close to γ Virginis throughout the month. Summer solstice is on June 21d 11h when the days in the northern hemisphere are longest. In the latitude of Greenwich the sun rises about 3h 40m and sets at 20h 22m, which implies 16h 40m of sunlight, but owing to twilight the actual period of darkness is considerably less than 7h 20m.

Those who are interested in observing the changes in the moon's appearance from night to night will notice that during the first week in June the moon sets later each night by a comparatively short interval, varying from about 10 to 20 minutes, but after this the interval increases rapidly so that between June 10 and 11 it is more than 1½ hours; e.g. on June 10 the moon sets at 5h 35m and the next day at 7h 5m, while on June 12 the time of setting is about 8h 35m. Careful observation will show that when the moon is south it is lower night by night until June 9, when it commences to move a little higher each night. Between June 1 and 12 there is a difference of about 33° in these altitudes, that is, when the moon is south it is 33° nearer the horizon on June 9 than it was on June 1. All these phenomena are explained by the fact that the moon's southern declination increases between June 1 and 8 after which it decreases, and on June 14 it is zero, that is, the moon lies then in the celestial equator and then continues to increase its northern declination until June 21.

C. T. R. Wilson and the Cloud Chamber

LAST October DISCOVERY printed an article by C. L. Boltz about C. T. R. Wilson and his Cloud Chamber which created much interest among our readers. Many of them will be much interested in a small monograph on the same topic which has been written by S. L. Barron and published by the Cambridge Instrument Co. Ltd., 13 Grosvenor Place, London, S.W.1. Copies are available, without charge, to any interested person.

The monograph is the fourth in the series which this company is issuing about the collaboration with its prominent men of science in devising and developing fundamental scientific instruments that have had marked effect on the progress of science and industry. The object of the monographs is to place on record the indebtedness of instrument makers to those men of science, and to detail the story of their collaboration before time blurs the records.

Sir Lawrence Bragg, director of the Cavendish Laboratory, contributes a foreword to the Wilson monograph in which he tells the following anecdote: "The Wilson cloud chamber is one of the most prized treasures of the Cavendish Museum, together with ancillary apparatus and his electroscope. I showed it to him last year, and asked whether this, certainly one of the most famous units of apparatus in the history of physics, was correctly described as the original Wilson Cloud-Chamber. Wilson thought for a little and then said with some surprise, 'But I never made but the one'." That answer of Wilson's will come as a surprise to most people who have not studied the history of the cloud chamber very minutely.

Special Problems of Stratosphere Flight

FLIGHT in the stratosphere is posing some odd scientific questions, as, for instance, that concerned with the increased wear of carbon brushes, the contacts of the aircraft's electrical power supply. At high altitudes the brushes disintegrate at a phenomenal rate; brushes which ordinarily last for years at ground level, wear down in the stratosphere at the rate of over half an inch an hour. If the brushes wear right down and break contact, the power supply fails. On a recent long-distance high-altitude flight by an Air Force jet aircraft this was within a fraction of an inch of happening. The high rate of wear is connected with the lack of moisture in the stratosphere. An obvious solution is to supply moisture to the commutators, but scientists found that a heavy jet bomber would take about 570 lb. of water, and alternative techniques have had to be developed.

Its low water-vapour content is one of the characteristic features of the stratosphere; it amounts to less than one-thousandth of the water-vapour content at ground level.

The stratosphere itself (which is defined as the level where temperature remains constant with height) varies from day to day and place to place. It may begin at 25,000 ft. above the poles or at 65,000 ft. above the equator. Test flights recently made over southern England to check its position found that it varied from 25,000 ft. to 37,000 ft., and temperatures ran from $-40°$C. to $-68°$C., while the lowest temperature ever recorded in the stratosphere, $-92°$C., was, paradoxically, over the equator.

Perhaps the most startling problem of stratospheric flight is the effect of temperature on metals. Metals meet trouble both ways—in the prevailing cold and, at high speeds, in the heat caused by their passage through the air. For instance, at 660 miles an hour, the surface temperature of a jet flying in the stratosphere might be $-13°$C. At 1320 miles an hour it would have gone up to $+118°$C. and at 1980 miles an hour it would be $+335°$C. Luckily, present-day speeds are low enough so that only the low temperatures need to be taken into account, though the higher speeds and temperatures are being kept in mind. When metals are cooled, they contract, their electrical resistance drops, and there are other effects, all of which happen only while the metal is at the low temperature, not permanently.

As an example of what this will mean, the fuselage of an aircraft made of contemporary materials, which in a temperate climate measures 80 ft. in length, may increase to 80 ft. 1½ in. if it stands about on a tropical airfield. If it takes off and flies up into the stratosphere, it might shrink by as much as 3·2 in. For these and other reasons, new materials are being developed and tested.

Yet in spite of all the difficulties, every advanced type of aircraft on the drawing-board in Britain today is designed for stratospheric flight. And scientists believe that, ultimately, the strength-reserve in an aircraft will be greater in the stratosphere, the reason being that flight is smoother, and airframe alloys are stronger at lower temperatures.

First Middle East Arid Zone Conference; World Scientists to meet in Ankara

TWENTY-SEVEN scientists from fifteen countries met in Ankara, Turkey, from 25 to 29 April, 1952, to discuss hydrology problems of the arid zones with special reference to underground water. This was the first meeting of its kind to be held in the Middle East, where these problems are most acute. The following countries were represented: Algeria, Australia, Egypt, France, India, Israel, Lebanon, Mexico, Morocco, Pakistan, South Africa, Syria, Turkey, the United Kingdom and the U.S.A. The proceedings of the symposium, for which Unesco and the Turkish Government are acting as co-sponsors, will be published by Unesco in English, French, Spanish and Arabic.

Just before the opening of this symposium, the Advisory Committee on Arid Zone Research, the body set up by Unesco two years ago to make recommendations to put into effect the programme of arid zone research, held a three-day meeting.

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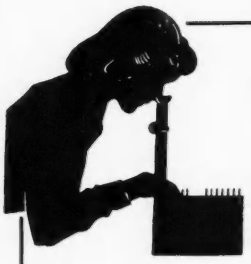

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